United States Patent [19]

Thomson

[11] **Patent Number: 4,550,559**

[45] **Date of Patent: Nov. 5, 1985**

[54] **CABLES AND PROCESS FOR FORMING CABLES**

[75] Inventor: **Ian M. Thomson**, Wokingham, England

[73] Assignee: **Cable Belt Limited**, Edinburgh, Scotland

[21] Appl. No.: **528,439**

[22] Filed: **Sep. 1, 1983**

[30] **Foreign Application Priority Data**

Sep. 1, 1982 [GB] United Kingdom 8224956
Jun. 2, 1983 [GB] United Kingdom 8315181

[51] **Int. Cl.**[4] **D07B 1/08;** D07B 1/10; D07B 1/16; D07B 7/14

[52] **U.S. Cl.** **57/223;** 57/215; 57/217; 57/219; 57/221; 57/7; 57/9

[58] **Field of Search** 57/215, 217, 219, 221, 57/223, 232, 234, 237, 248, 7, 9

[56] References Cited

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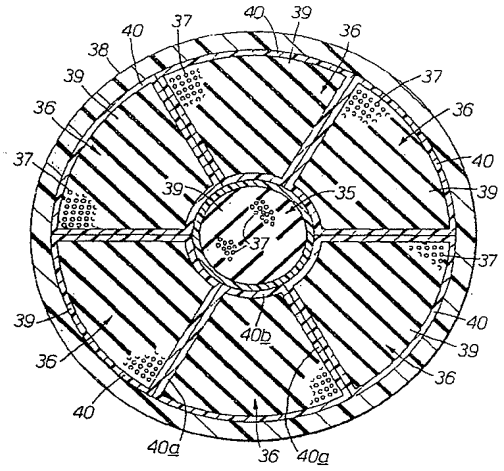
3,526,086	9/1970	Morgan	57/223 X
3,911,785	10/1975	Hood	57/234 X
4,059,951	11/1977	Roc	57/215 X

Primary Examiner—Donald Watkins
Attorney, Agent, or Firm—Leydig, Voit & Mayer, Ltd.

[57] **ABSTRACT**

A cable comprises at least one layer of strands (**10**) with each strand covered with an individual sheath (**20**) of rubber or plastics material. The sheaths are so shaped (**16, 17, 18**) that the sheaths of adjacent strands interlock. This provides a layer in which the strands have a generally fixed spatial relationship both to each other and within the cable. This reduces inter-strand forces, so increasing cable life, and also provides a dimensionally stable cable.

25 Claims, 7 Drawing Figures



US005732875A

United States Patent [19]

Ziemek et al.

[11] Patent Number: 5,732,875

[45] Date of Patent: Mar. 31, 1998

[54] **METHOD FOR PRODUCING A SECTOR CONDUCTOR FOR ELECTRIC POWER CABLES**

[75] Inventors: **Gerhard Ziemek; Michael Meyer**, both of Langenhagen, Germany

[73] Assignee: **Alcatel Kabel AG & Co.**, Germany

[21] Appl. No.: **668,096**

[22] Filed: **Jun. 18, 1996**

[30] **Foreign Application Priority Data**

Jun. 22, 1995 [DE] Germany 195 22 628.3

[51] **Int. Cl.**[6] **B23K 31/02**; B21D 39/00

[52] **U.S. Cl.** ..... **228/148**; 228/156; 174/129 R

[58] **Field of Search** ..... 228/130, 148, 228/156, 147; 174/128.2, 129 R, 129 S

[56] **References Cited**

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FOREIGN PATENT DOCUMENTS

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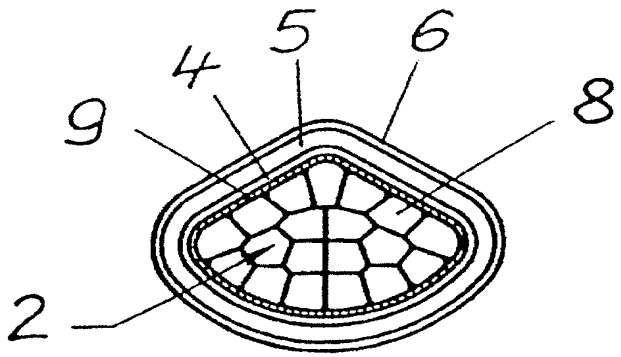
Book entitled "Introduction to Electric Power Cable Technology part 2, type process I, from the Cable and Metal Works Gutehoffnüngshutte (Good Hope Smeltery) AG, Apr. 1969.

Primary Examiner—P. Austin Bradley
Assistant Examiner—Jeffrey T. Knapp
Attorney, Agent, or Firm—Ware, Fressola, Van der Sluys & Adolphson LLP

[57] **ABSTRACT**

A method for producing a sector conductor for electric power cables is introduced, whereby a number of metal wires are joined closely together into a core (**8**) with a sector-shaped cross section. A lengthwise running metal strip is formed around the core (**8**) and its longitudinally abutting edges are welded into a tube (**9**), whose dimensions are reduced so that it lies closely against the core (**8**) and surrounds it.

5 Claims, 1 Drawing Sheet



United States Patent [19]

Dyba et al.

[11] **3,914,532**

[45] **Oct. 21, 1975**

[54] **SECTOR CABLE**

[75] Inventors: **John J. Dyba**, New York, N.Y.; **Carl F. Ackerman**, New Hope, Pa.

[73] Assignee: **The Anaconda Company**, New York, N.Y.

[22] Filed: **Apr. 11, 1974**

[21] Appl. No.: **460,126**

[52] **U.S. Cl.** ..... **174/119 R**; 174/110 P; 174/114 S

[51] **Int. Cl.**[2] **H01B 7/02**

[58] **Field of Search** ..... 174/114 S, 129 S, 110 P, 174/119 R; 162/138, 206

[56] **References Cited**

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2,624,245	1/1953	Cluett	162/206
3,662,092	5/1972	Franco	174/110 P

FOREIGN PATENTS OR APPLICATIONS

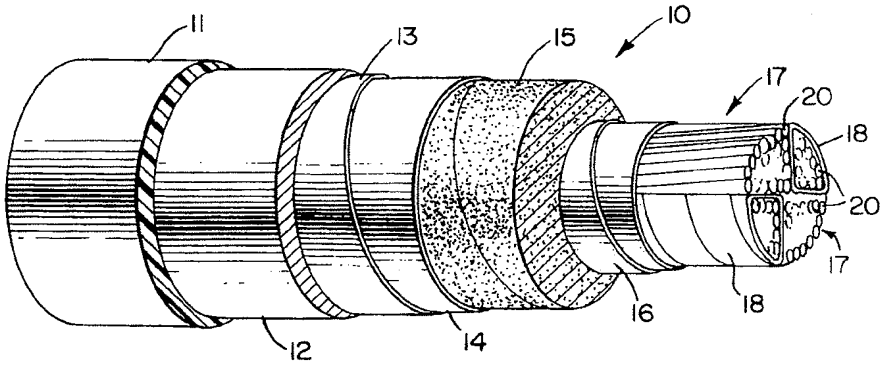
63,542	3/1949	Netherlands	174/114 S

Primary Examiner—E. A. Goldberg
Attorney, Agent, or Firm—Pennie & Edmonds

[57] **ABSTRACT**

A sector cable comprising a plurality of wedge-shaped, segments, composed of a plurality of compacted and twisted wire strands, arranged with side walls abutting and with the point of each wedge directed toward, but spaced from, the central axis of the cable, at least alternate segments covered on the exterior with an insulation covering comprising at least two layers of an extensible, flexible, and dense, uncreped paper, the insulated and uninsulated segments being so spaced in relation to each other that the side wall of any uninsulated segment does not abut the side wall of any other uninsulated segment.

3 Claims, 3 Drawing Figures



July 12, 1938. H. ROST 2,123,746

INSULATED CABLE

Filed Aug. 30, 1933

Fig. 1.

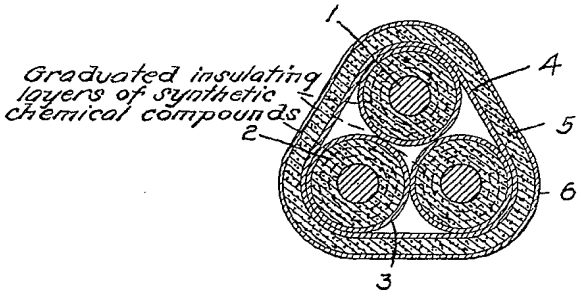


Fig. 2.

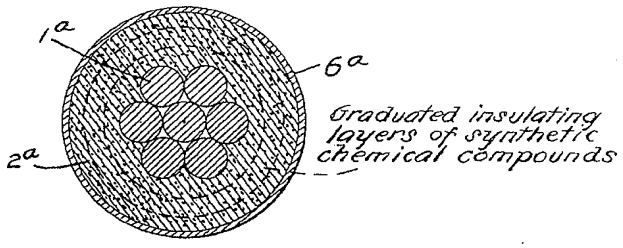
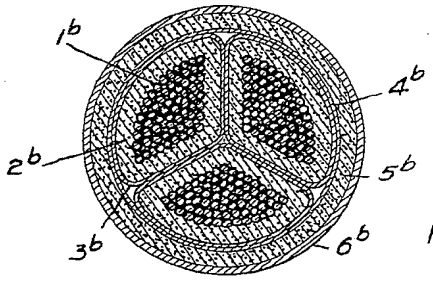


Fig. 3.



Helge Rost
INVENTOR
BY Otto Munk
his ATTORNEY.

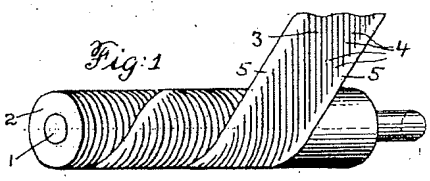
P. H. CHASE.

CABLE AND METHOD OF MAKING THE SAME.

APPLICATION FILED NOV. 2, 1916. RENEWED AUG. 9, 1920.

1,370,731. Patented Mar. 8, 1921.

Fig. 1



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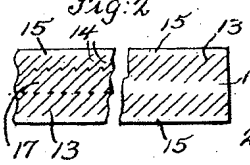

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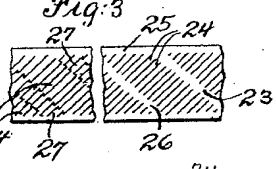

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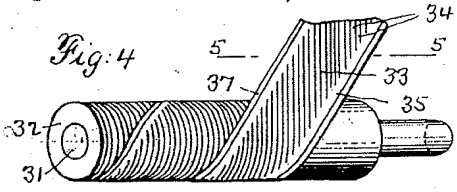

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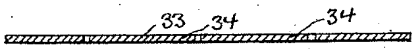

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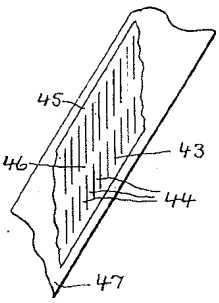

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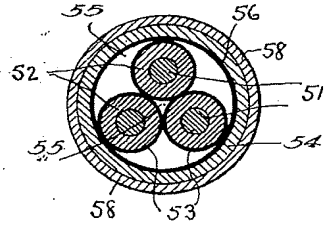

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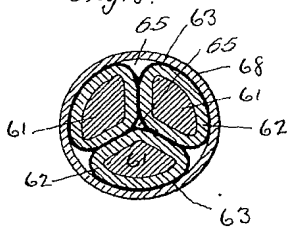

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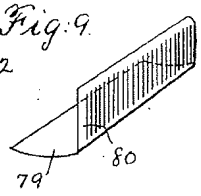

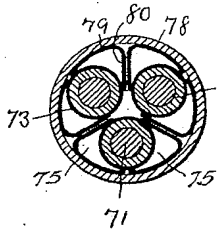

Inventor

Philip H. Chase.

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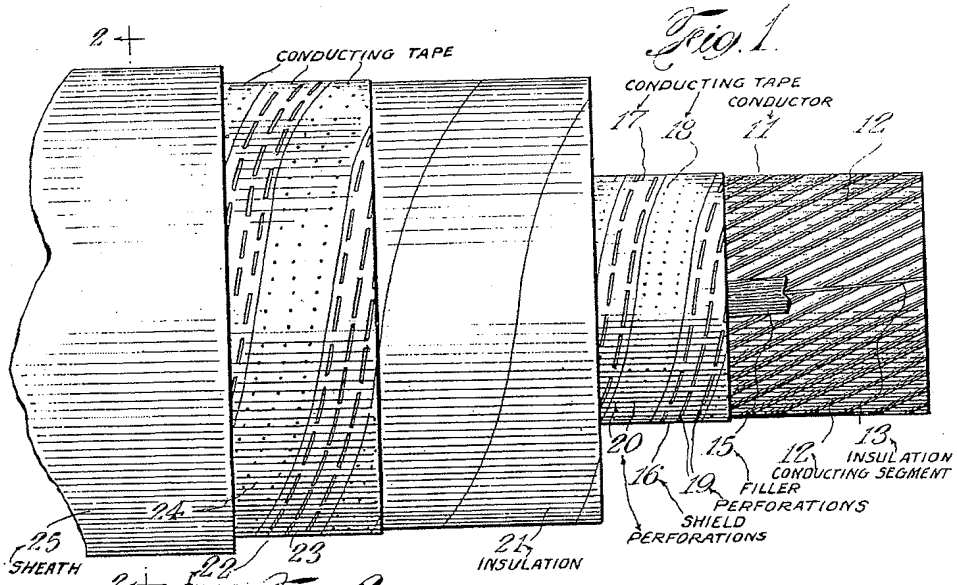
Emery, Booth, Janney & Varney

Aug. 9, 1938. R. W. ATKINSON 2,125,869

ELECTRICAL CONDUCTOR

Filed July 18, 1933 2 Sheets-Sheet 1

Fig. 1.



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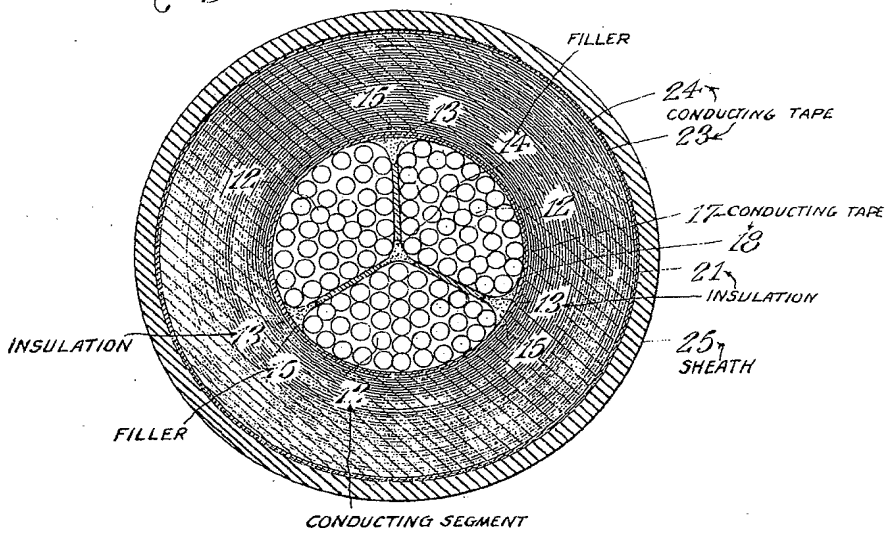

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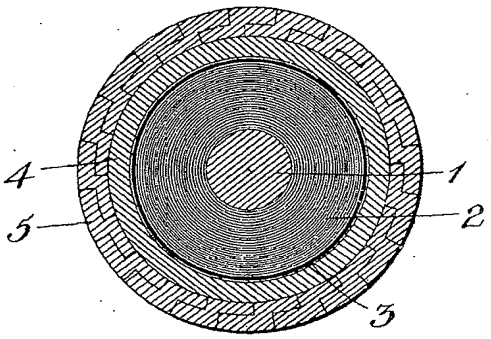
ELECTRICAL CONDUCTOR.

APPLICATION FILED MAR. 27, 1913.

Patented Oct. 3, 1916.

1,199,789.

Fig. 1.



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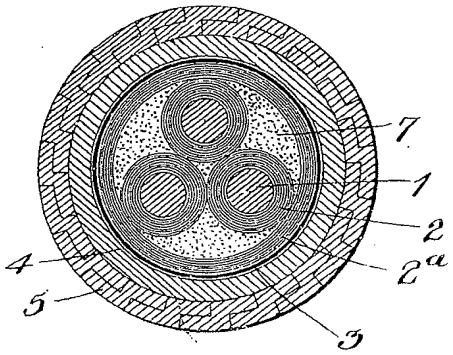

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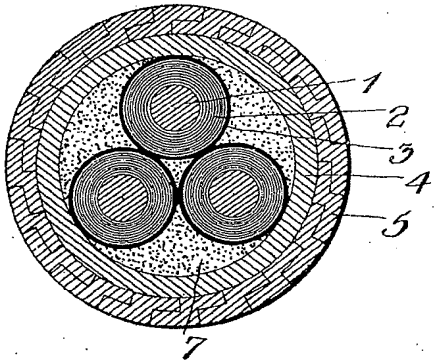

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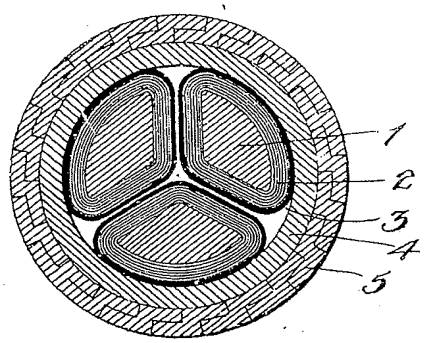

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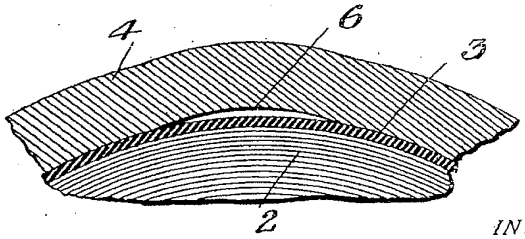

WITNESSES

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Carolino Morgan.

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March 7, 1967 W. J. GILMORE ET AL 3,307,343

CORROSION RESISTANT WIRE ROPE

Filed May 27, 1965

FIG. 1

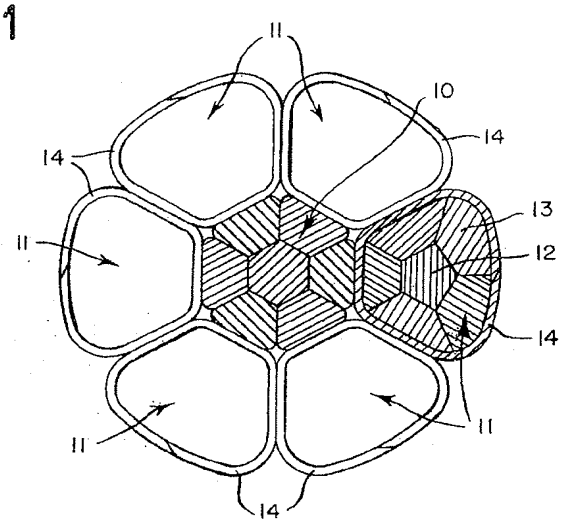
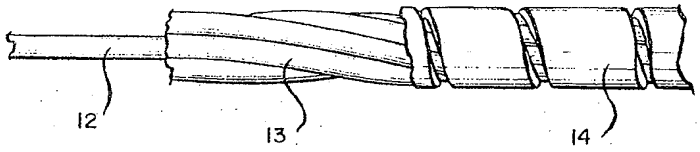


FIG. 2



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Dennis, Edmonds, Morton, Taylor & Adams
ATTORNEYS

May 22, 1934. W. A. DEL MAR 1,959,526

MULTICONDUCTOR SHIELDED CABLE

Filed May 19, 1928

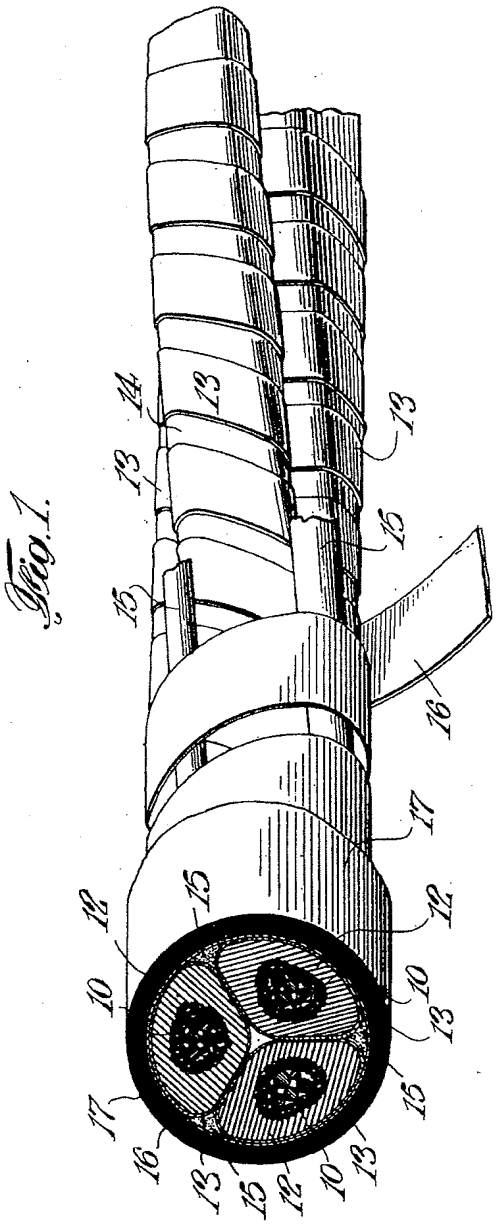

Fig. 1.

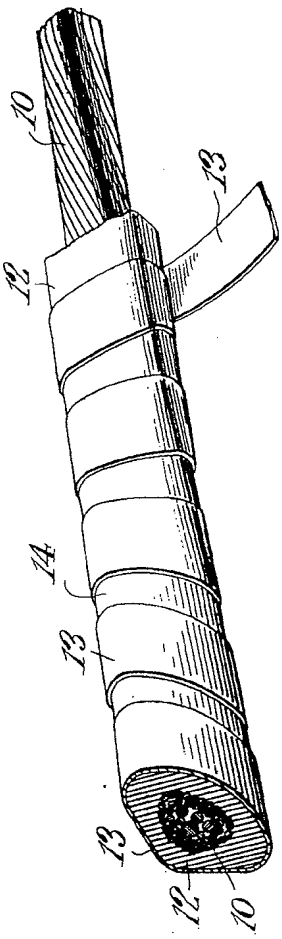

Fig. 2.

INVENTOR.
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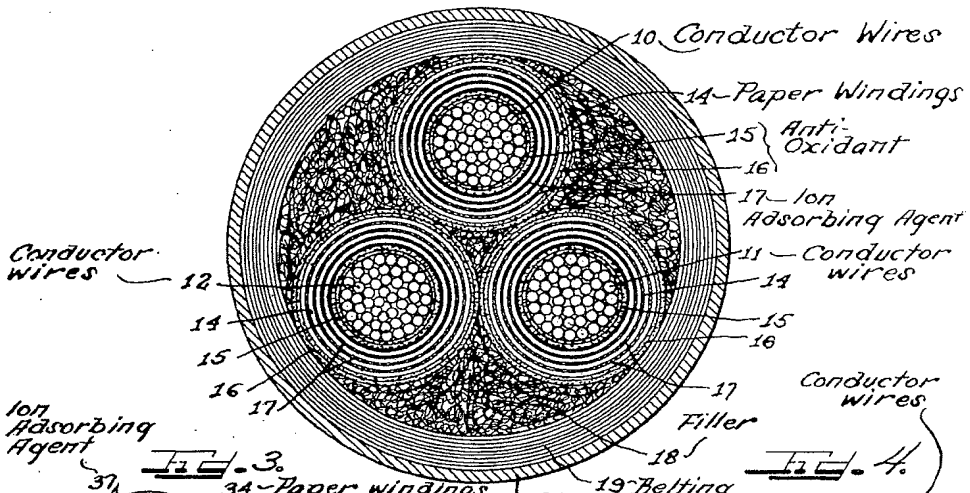
Cooper, Kerr & Dunham.
ATTORNEYS.

March 29, 1938. K. S. WYATT 2,112,322

CABLE

Filed Jan. 18, 1935

Fig. 1.



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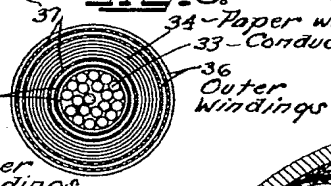
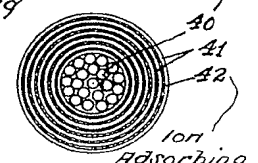
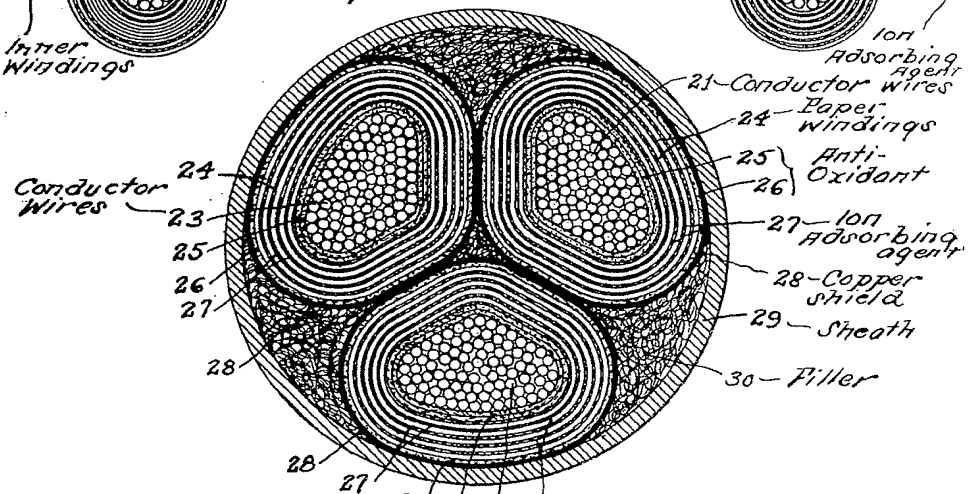


Fig. 2.

Fig. 4.





Inventor

Kenneth S. Wyatt.

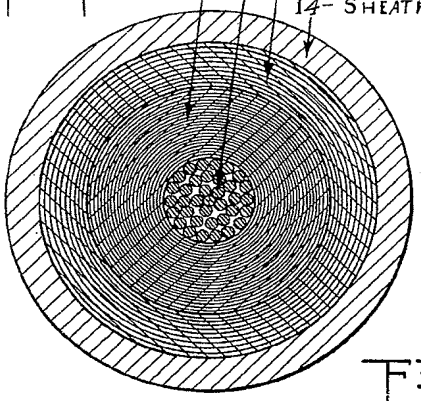
By Charles A. Sheld Atty

Feb. 13, 1940. W. A. DEL MAR 2,190,017

ELECTRIC CABLE

Filed June 16, 1938

Fig. 1.



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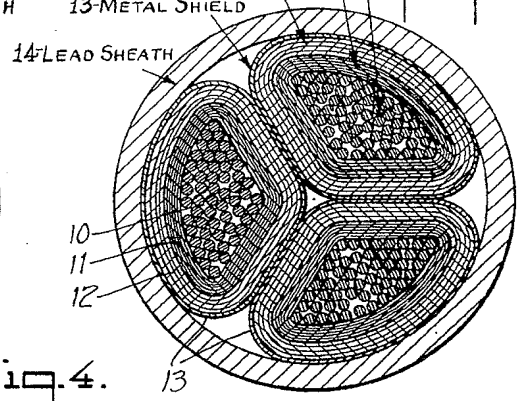

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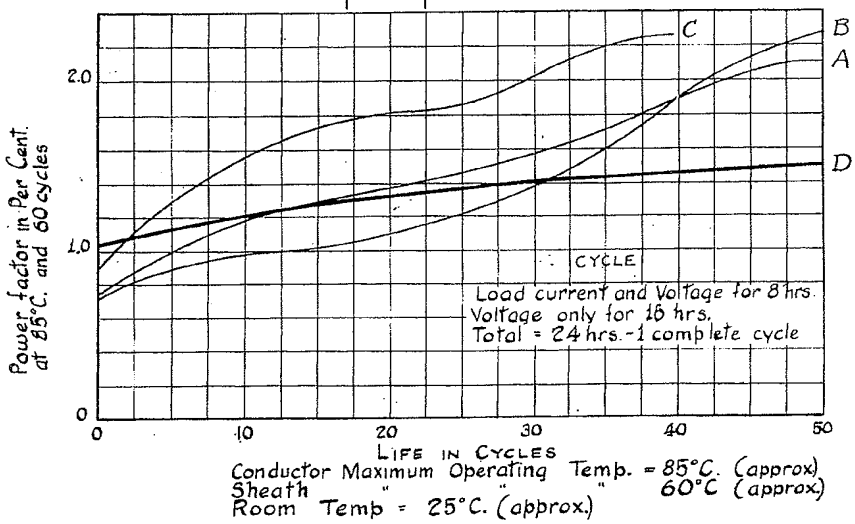


Conductor Maximum Operating Temp. = 85°C. (approx)
Sheath " " " = 60°C (approx)
Room Temp = 25°C. (approx.)

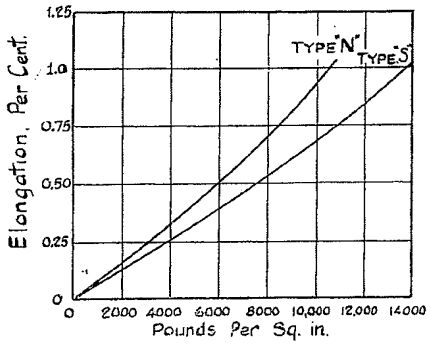


Fig. 3.

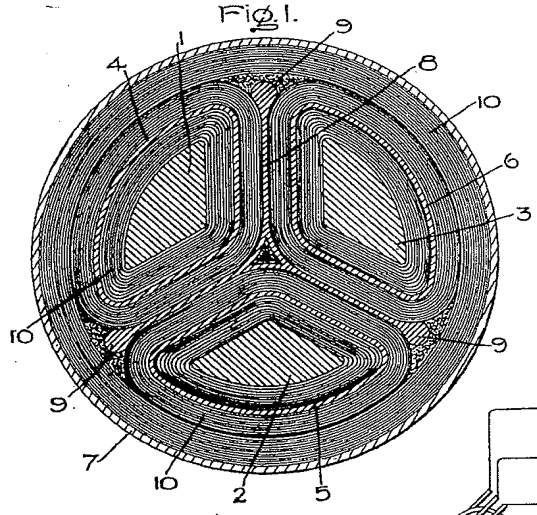
INVENTOR
William A. Del Mar
BY
Edwin Vanderwerker
ATTORNEY

Sept. 8, 1931. V. KARAPETOFF 1,822,737

POLYPHASE INTERSHEATH CABLE

Filed Dec. 7, 1929

Fig. 1.



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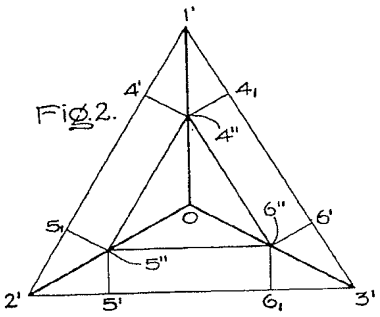

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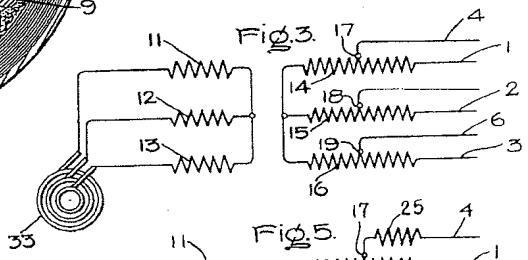

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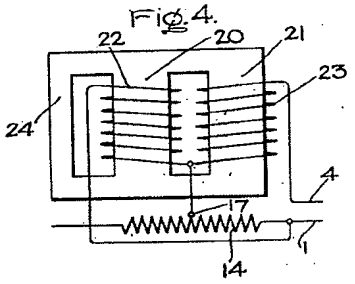


Fig. 5.

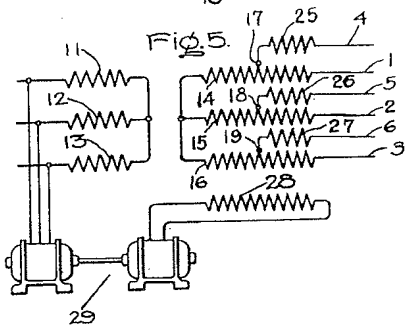
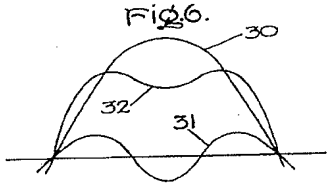


Fig. 6.



Inventor:
Vladimir Karapetoff,
by Charles E. Mullen
His Attorney.

A. M. J. E. REBOUL.

FOLDING SAFETY RAZOR.

APPLICATION FILED NOV. 3, 1913.

1,393,700. Patented Oct. 11, 1921.

Fig:1.

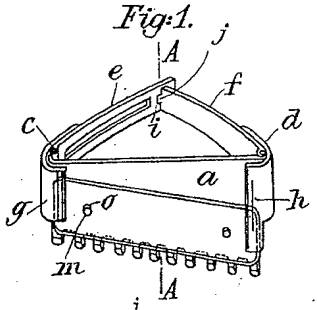


Fig:2.

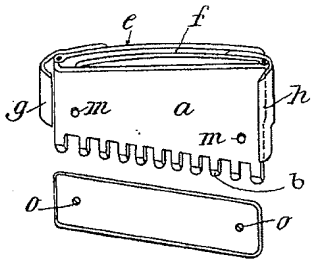


Fig:3.

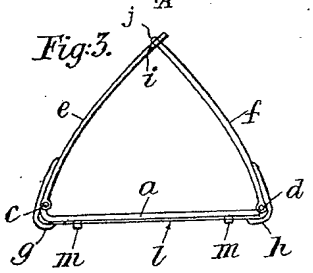


Fig:4.

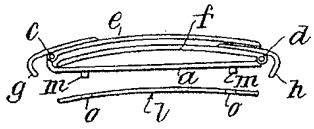
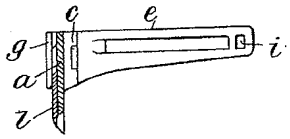


Fig:5.



Witnesses:
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Attorney.

(No Model.)

W. H. SAWYER.

ELECTRIC CABLE.

No. 269,470. Patented Dec. 19, 1882.

Fig. 2.

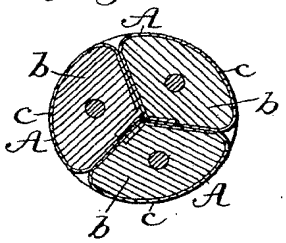

Fig. 1.

Fig. 3.

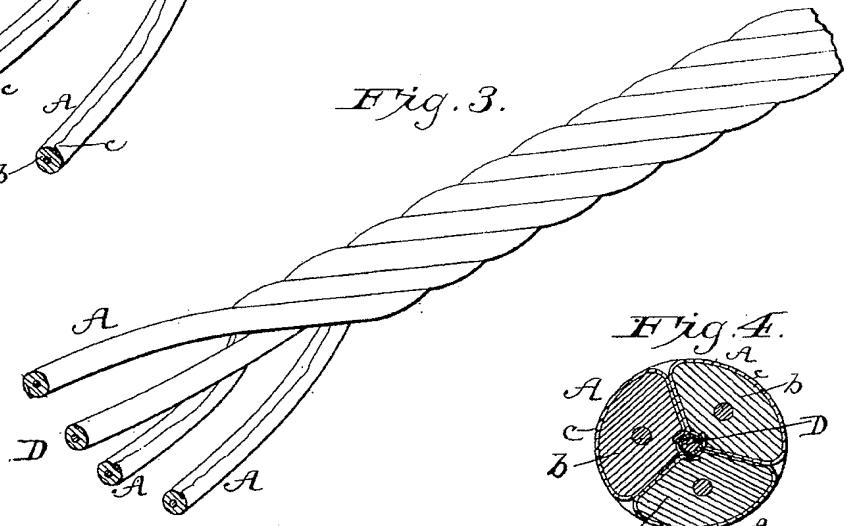

Fig. 4.

Witnesses:
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by Fred. H. Royce,
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PATENT SPECIFICATION (11) 1 387 660

1 387 660

(21) Application No. 40713/72 (22) Filed 1 Sept. 1972

(31) Convention Application No. 2 162 210

(32) Filed 15 Dec. 1971 in

(33) Germany (DT)

(44) Complete Specification published 19 March 1975

(51) INT. CL.[2] H01B 7/28 9/00

(52) Index at acceptance

H1A 1C 2E3D3 4S

(72) Inventors SIEGFRIED RICHTER and HANS-MARTIN SCHMIDTCHEN

(54) ELECTRICAL CABLE

(71) We, KABEL- UND METALLWERKE GUTEHOFFNUNGSHUTTE AKTIENGESELLSCHAFT, a body corporate organised under the laws of Germany, of 271, Vahrenwalder Strasse, Hannover, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to an electrical power cable.

Known low tension power cables comprise a plurality of plastics material insulated conductors each consisting of a plurality of compressed aluminium cores, the conductors being of either circular or sector-shaped cross-section. In cables of this kind damage to the insulation may remain undetected for a long time if a short-circuit is not caused at the instant when the damage occurs, since, in contrast to paper insulated cables, plastics material insulation is not sensitive to moisture, so that even if a conductor is exposed by any damage, breakdown of the cable does not necessarily result.

If the conductors of a damaged cable are of copper, the cable installation is not necessarily endangered by the damage. An exposed aluminium conductor, however, corrodes in the course of time, until finally the conductor breaks. If the conductor is a phase conductor, the current path is interrupted and the damage becomes noticeable through loss of current. If, however, the conductor broken by corrosion is serving as the protective conductor, the breakage will not at first be noticed. Only when the protective conductor is needed, for example on occurence of an insulation fault in an appliance connected to the cable, is the damage discovered. Hence, the cable installation can remain not electrically isolated for some time, so that persons coming into contact with the installation are in danger.

It has already been attempted to prevent corrosion of multi-core aluminium conductors in low tension electrical cables by treating the cores forming the conductor by impregnating the surfaces thereof next to the surrounding plastics material insulation with a corrosion-inhibiting, adhering wax-like composition which is not liable to crack. Apart from the fact that the application of such a composition constitutes an additional operation during manufacture of the cable, the composition does not always meet the demands made on it, particularly as there is a constant risk that it may be rubbed off, even during manufacture.

According to the invention there is provided an electrical power cable comprising a plurality of conductors at least one of which consists of a plurality of compressed aluminium cores each individually covered with a layer of a metallic material, which material has a higher resistance to corrosion than the aluminium of said cores, the covered cores of the or each such conductor being contained in an individual sheath of electrically insulating plastics material.

With the cable of the invention a covering layer covers each core of the conductor individually, and thus prevents the propagation of local corrosion phenomena, from one core to neighbouring cores. Cables according to the invention can, without difficulty, be manufactured with existing manufacturing equipment, since the construction of the cables is no different to the construction of an ordinary cable. Moreover, ordinary commercial terminals and connectors can be used on the cable of the invention, so that no installation difficulties arise. Preferably said covering layers are of copper. Each of the covering layers can consist of a thin copper strip formed into a tube and welded at the edges.

Preferably all the conductors are contained in a common sheath of electrically insulating plastics material.

Two embodiments of cable according to the invention will now be described by way

[*Price 33p*]

1387660 COMPLETE SPECIFICATION
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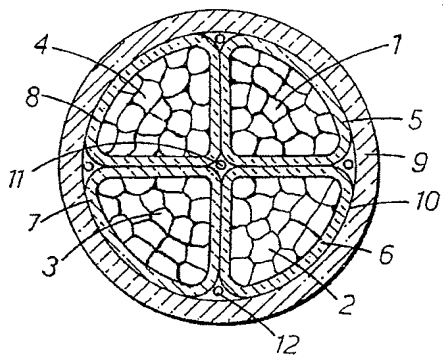
Fig.1.



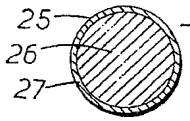


Fig.2.

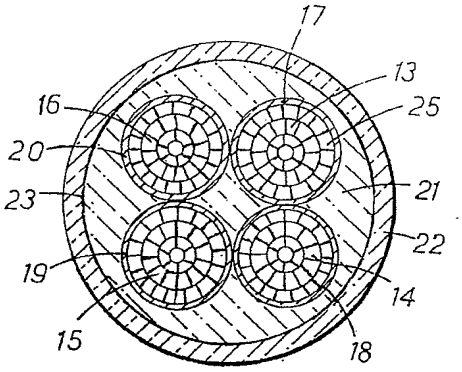


Fig.3.

(12) UK Patent Application (19) GB (11) 2 095 459 A

(21) Application No 8206446
(22) Date of filing 4 Mar 1982
(30) Priority data
(31) 3111468
(32) 24 Mar 1981
(33) Fed. Rep of Germany (DE)
(43) Application published
29 Sep 1982
(51) INT CL³
H01B 9/00
(52) Domestic classification
H1A 3E 4A 4B
(56) Documents cited
None
(58) Field of search
H1A
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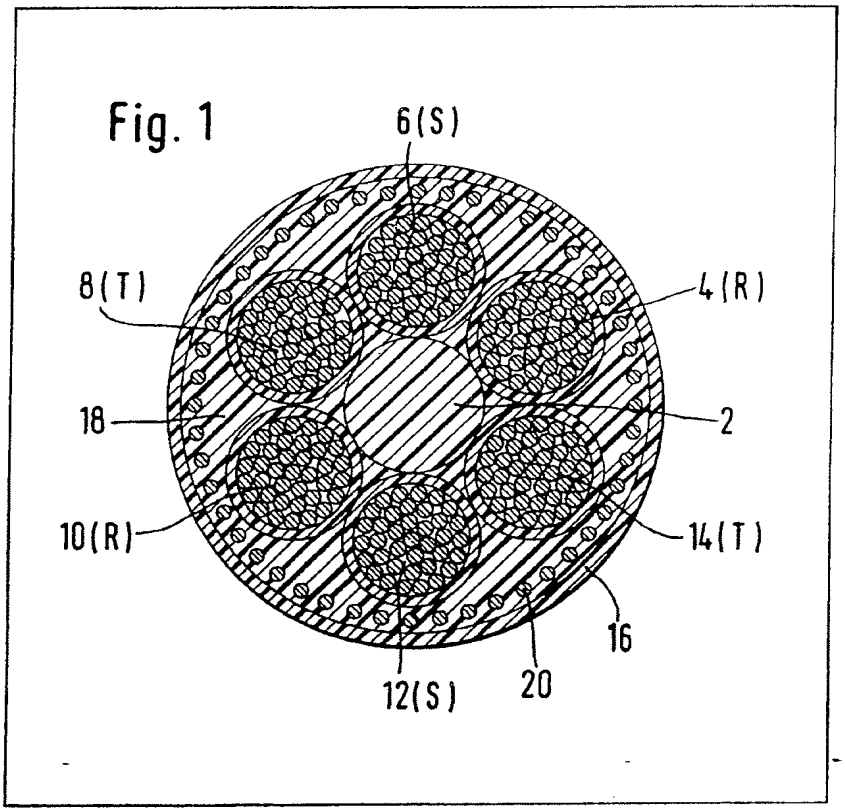
(54) **A high-current cable for medium-frequency three-phase current**

(57) A high-current cable for medium-frequency three-phase current has six phase conductors 64 to 14 of the same cross-sectional area and shape symmetrically arranged around a cable core 2 and a null or protective conductor 20 surrounding the phase conductors. In a cable of this kind the loop impedance is significantly decreased relative to a cable having a null or protective conductor situated at the centre of the cable. Alternatively the phase conductors may be sector shape in cross-section (Figure 2 not shown) give to a further decrease in the loop impedance phase against phase and to decrease the external diameter of the cable for the same conductor cross-sectional area and, as a result of this, to increase in flexibility of the cable. The conductors 4 to 14 may be enamel-insulated conducting strands and the outer sheath 40 corrugated copper. The core 2 may be solid or stranded plastics. Diametrically opposed conductors are connected to the same phase.



GB 2 095 459 A

Fig. 1

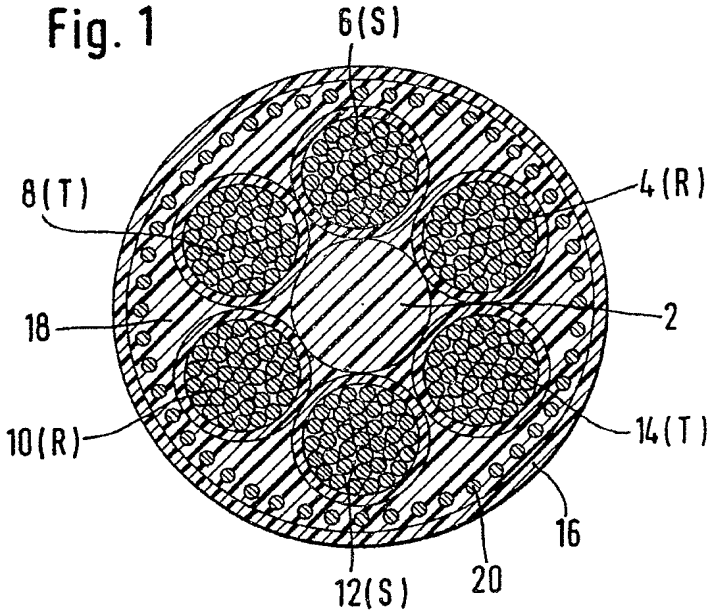
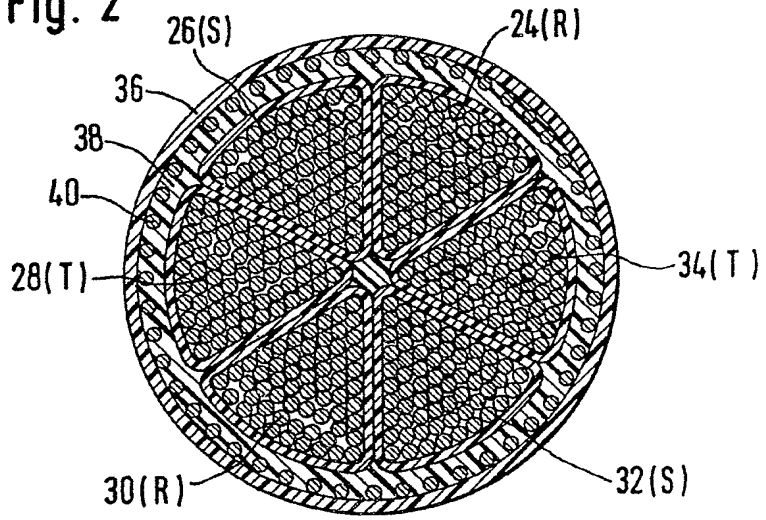


Fig. 2



SPECIFICATION

A high current mains for medium frequency three phase current and a high current cable for medium frequency three phase current.

The invention relates to a high current mains for medium frequency three phase current where a mains cable has six phase conductors of the same cross-sectional area and shape arranged symmetrically around the core of the cable, two of the said conductors, situated diametrically opposite each other, being for each phase connected together at the ends of the cable as the conductor for that phase and the mains cable having a null or protective conductor arranged symmetrically with respect to the phase conductors. The invention also relates to a high current cable for carrying medium frequency three phase current having six phase conductors of the same cross-sectional area and shape arranged symmetrically around the cable core and having a null or protective conductor situated symmetrically with respect to said phase conductors.

A known mains cable of the type referred to is described in our Patent Application No. 80300584 (Specification No. 2059670A) for medium frequency three phase current, in particular a mains supply having a frequency of 400 Hz or over. This known cable has a null or protective conductor arranged at the centre of the cable around which the six phase conductors are arranged symmetrically and, in particular, in a stranded arrangement. Mains cables of this type are characterised by low losses, high load capacity because of large surface area, low stray field, low inductance and a symmetrical construction.

It is an object of the invention, for high current cables of the type described in the opening paragraph hereof, to decrease further the losses and in particular to decrease the loop impedance, particularly the impedance between the phase and the null conductors.

This object is solved according to the invention by providing a cable in which the null or protective conductor surrounds the phase conductors as an external conductor concentric with the core. The loop impedance of such a cable between the phase conductors and the null or protective conductor is significantly reduced.

A further improvement with respect to a cable in accordance with the invention is that instead of the cable having phase conductors of circular cross-section, the cable has phase conductors which are substantially sector shape in cross-section. In a cable having sector-shaped phase conductors the loop impedance, phase against phase, is approximately 15% less than that obtained with the use of conductors of circular cross-section.

The cable having phase conductors has the additional advantage of a smaller diameter for the same predetermined copper cross-section. The cable is thus more flexible.

The design of the null or protective conductor as an external conductor has, in addition, the known advantage that in mechanical stresses this conductor makes contact with the exterior before contact with the phase conductors has occured. Three phase current cables having a null or protective conductor designed as an external conductor are, in themselves, known as NYCY-cables in which the three phase conductors are arranged at equal distances from one another. Such a cable is, however, not suitable for the transmission of medium frequency three phase current since, in this case, there is a very high decrease in reactive voltage and with large cross-sections very high transmission losses.

Cables in accordance with the invention are illustrated in the accompanying drawings in two embodiments and are described in more detail in the following with reference to the drawings. In the drawings,

Figure 1 is a cross-section through a cable having circular conductors, and

Figure 2 is cross-section through a cable having conductors in the form of sectors.

The cable illustrated in the Figure 1 has six phase conductors 4, 6 8, 10, 12 and 14 which are arranged symmetrically around the core of the cable. The cable core 2 has a circular profile and may, for example, be either formed from solid synthetic plastics material or from individual strands of synthetic plastics material.

The phase conductors 4, 6, 8, 10, 12 and 14 are constructed in the usual way from stranded individual wires. In the illustrated cable the individual wires are, preferably, separately insulated. Wires insulated with enamel are preferably used as the individual wires. The current displacement or skin effect is kept low by insulating the individual wires separately.

The complete phase conductors 4, 6, 8, 10, 12 and 14 are each surrounded by an insulating material and are designed as circular conductors. The phase conductors are embedded in an insulating mass 18. An external conductor 20, consisting of separate wires, is provided externally around the assembly of phase conductors 4, 6, 8, 10, 12 and 14 and is provided on its outer peripheral surface with a non-conducting coating or shield 16 which conveniently consists of synthetic plastics material and which gives protection against damp and mechanical damage. The external conductor 20 preferably consists of copper. It may be designed, in a known manner, as a corrugated copper casing.

Cables of this type described herein may have conductor cross-sections of up to 250 mm^2. In high current mains for medium frequency three phase current two diametrically-opposite phase conductors, thus conductors 4 and 10, 6 and 12 and 8 and 14 are, in each case, connected in parallel so that each of the phases R, S and T has two individual conductors arranged symmetrically diametrically-opposite one another. These conductors are in each case connected together at the ends of the cable.

In the cable shown in Figure 2 the six phase conductors 24, 26, 28, 30, 32 and 34 are each designed to have a cross-sectional shape in the form of a sector. In this way it is possible to reduce the external diameter of the six phase conductors for equal copper cross-sectional area as compared with

that produced by the use of circular conductors. The individual conductors of sector form are provided with external insulation. Any remaining hollow spaces are filled with an insulating mass. At the least a layer 38 of an insulating mass is mounted externally around the conductors of sector form, on or in which the external casing 40 is arranged. In this case again the casing 40 consists of copper and is conveniently designed as a corrugated copper casing. The cable is provided externally with a non-conducting annular coating or shield 36 as a protection against moisture and mechanical damage.

In comparison with the cable shown in Figure 1, the cable shown in Figure 2 has the advantage of a smaller external cross-section for the same cross-sectional area of conductors and is thus more flexible so that it is easier to lay. In addition the cable having conductors of sector form has a very low impedance, phase against phase. The loop impedance is approximately 15% lower than in the embodiment shown in Figure 1. In the cable shown in Figure 2, when in use in high current mains, diametrically-opposite conductors which respectively represent the phases R, S and T are connected together at the cable ends, for each phase.

CLAIMS

1. A high current mains for medium frequency three phase current in which the mains cable has six phase conductors of the same cros-sectional area and shape and symmetrically arranged around the cable core, of which two diametrically-opposite conductors are, for each phase, connected together at the ends of the cable as the conductor for that phase and in which the mains cable has a null or protective conductor arranged symmetrically with respect to the phase conductors and surrounding the phase conductors as an external conductor concentric with the core.

2. A high current mains according to Claim 1, in which the phase conductors of the mains cable are in cross-section of substantially sector shape.

3. A high current cable for three phase current mains of medium frequency, having six phase conductors of the same cross-sectional area and shape and symmetrically arranged around a cable core and a null or protective conductor situated symmetrically with respect to said phase conductors and surrounding the phase conductors as an external conductor concentric with the core.

4. A cable according to Claim 3, in which the six phase conductors are in cross-section of substantially sector shape.

5. A cable according to Claim 3 or 4, in which each phase conductor is formed from a plurality of individual wires, each being covered by insulation.

6. A cable according to Claim 5, in which the individual wires are insulated by means of an enamel coating.

7. A cable according to any one of Claims 3-6 in which the null or protective conductor is a corrugated tubular casing.

8. A cable according to any one of Claims 3-7 in which the null or protective conductor is enclosed within an outer non-conducting coating or shield.

9. A high current cable for three phase current mains of medium frequency constructed and arranged substantially as described herein with reference to Figure 1 or 2 of the accompanying drawings.

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Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

PATENT SPECIFICATION (11) 1 362 519

1 362 519

(21) Application No. 44060/70 (22) Filed 15 Sept. 1970 (19)

(23) Complete Specification filed 15 Sept. 1971

(44) Complete Specification published 7 Aug. 1974

(51) International Classification H01B 9/00

(52) Index at acceptance

H1A 10 2E3D3 3E 4B 6S 9

(72) Inventor ERIC WILLIAM PATRICK WEBBER

(54) ENVELOPED-NEUTRAL-TYPE, LOW-VOLTAGE ELECTRIC CABLES

(71) We, DELTA ENFIELD CABLES LIMITED, formerly Enfield-Standard Power Cables Limited, of Millmarsh Lane, Brimsdown, Enfield, Middlesex, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to low voltage cables designed to operate at phase-to-phase voltages of up to 1000 volts in so-called protective multiple earthing (PME) systems in which the neutral conductor is also used as an earth continuity.

In such cables, the conventional four core arrangement may be replaced by an arrangement consisting of three cores enclosed within either a single concentric neutral conductor in the form of a metallic sheath, or within multi-enveloped neutral conductors or wires as in the case of an armour, over the insulated cores. The form of concentric neutral conductor will depend on the type of insulating material used for the phase conductors. The neutral conductor is protected by an outer sheath.

For such cables to be employed in a PME system, it is necessary to satisfy the following requirements:

(a) Conductivity of the neutral conductor or conductors should preferably be the same, and in any case must not be less than 50% of that of the phase conductor.

(b) The integrity and continuity of the neutral conductor must be preserved.

(c) The cable design must be such as to permit easy connection to a service cable without severing the phase and neutral conductors when the cable is electrically alive, and

(d) Accessibility and easy identification of phase conductors must be provided for.

The present invention in its preferred form provides a multi-core enveloped-neutral-type low voltage electric cable for PME systems which meets the above conditions whilst being of compact construction.

According to the present invention, there is provided an envelope-neutral type, low-voltage electric cable comprising three individually insulated phase conductors of diamond-shaped cross-section having two opposite angles of 60° and two opposite angles of 120° each, which are laid up helically so that their combined cross-section throughout the length of the cable is hexagonal, six neutral conductors laid up helically with the same pitch as the phase conductors and arranged in pairs with the neutral conductors of each pair lying respectively against the two outwardly facing surfaces of a corresponding one of the insulated phase conductors, a winding of metal tape applied around the assembly constituted by the phase conductors and the neutral conductors and in electric contact with at least four of said neutral conductors throughout the length of the cable and a sheath of flexible electrically insulating material enclosing the said assembly and the tape applied around it.

Each of the neutral conductors preferably has, on that side thereof which is applied against an outwardly facing surface of the corresponding phase conductor, a flat surface of substantially the same width as the said outwardly facing surface and, on the opposite side, a part-cylindrical surface the centre-line of which is co-axial with the centre-line of the cable. Consequently the assembly around which the metal tape is wound has a cylindrical outer surface.

The phase conductors, the neutral conductors and the metal tape may be of aluminium, while the insulation around each phase conductor and the external sheath may consist of an elastomeric plastics or other like material.

To facilitate phase identification, one conductor of each pair of neutral conductors corresponding to two of the phase conductors may be individually coloured with a

[Price 25p]

corrosion-inhibiting paint, in which case the insulation of all three phase conductors can be of the same colour, e.g. black.

The metal tape, which may be helically wound over the six neutral conductors with a small gap between successive turns, may serve not only for providing electrical connection between all six, or at least four of the neutral conductors if the other two are coloured with a corrosion-inhibiting paint, but also for providing mechanical protection.

The construction of the cable according to this invention also has the advantage that the phase conductors are readily accessible without the need for severing the neutral conductors.

Furthermore, the three phase conductors and the six neutral conductors of this cable are laid up to give most effective utilisation of the space inside a circular cable.

Finally, with six separate neutral conductors as described above, the integrity and continuous earthing of the whole system is preserved.

The invention will now be described by way of example with reference to the accompanying drawing which shows a cross-section of a preferred form of the cable according to this invention.

Referring to the drawing, the cable shown is a three-phase cable having phase conductors 1, 2 and 3 of diamond-shaped cross-section. The phase conductors 1, 2, and 3 which are made of solid aluminium, correspond respectively to the three phases. All three conductors are provided with insulation as shown at 4. The combined cross-section of the three phase conductors is substantially hexagonal. Three pairs of neutral conductors 1A 1B, 2A 2B, and 3A 3B, which are also made of solid aluminium, correspond respectively to the three phases along the whole length as they are wound with the same pitch of lay as the phase conductors. Any one of the two neutral conductors of any two of the three phases may be coloured, e.g. painted with a corrosion-resistant coloured paint, for identification of the corresponding phase conductors.

The three phase conductors and the six neutral conductors are laid up with a suitable pitch (for example 1.3m) and assembled by means of a helically wound aluminium tape 5 so as to ensure continuous mechanical and electrical protection.

An outer sheath 6 of a plastics or elastomeric material is provided around the cable.

In order to make a service branch or T-joint from any of the phase conductors 1, 2 or 3 of the cable, owing to the choice of pitch during laying-up, it is easy to displace the two neutral conductors from the phase conductors over a certain length without severing them. Owing to the fact that there are six neutral conductors continuity may be preserved even if one or two neutral conductors were severed. It is also easy to identify the phase required. The phase conductor may then be exposed as necessary to make the T-joint.

WHAT WE CLAIM IS:—

1. An enveloped-neutral type, low voltage electric cable comprising three individually insulated phase conductors of diamond-shaped cross-section having two opposite angles of 60° and two opposite angles of 120° each, which are laid up helically so that their combined cross-section throughout the length of the cable is hexagonal, six neutral conductors laid of helically with the same pitch as the phase conductors and arranged in pairs with the neutral conductors of each pair lying respectively against the two outwardly facing surfaces of a corresponding one of the insulated phase conductors, a winding of metal tape applied around the assembly constituted by the phase conductors and the neutral conductors and in electric contact with at least four of said neutral conductors throughout the length of the cable and a sheath of flexible electrically insulating material enclosing the said assembly and the tape applied around it.

2. A cable as claimed in claim 1 wherein each of the neutral conductors has, on that side thereof which is applied against an outwardly facing surface of the corresponding phase conductor, a flat surface of substantially the same width as the said outwardly facing surface and, on the opposite side, a part-cylindrical surface the centre-line of which is co-axial with the centre-line of the cable.

3. A cable as claimed in any of the preceding claims in which the phase conductors, the neutral conductors and the metal tape are of aluminium.

4. A cable as claimed in any of the preceding claims, in which the insulation around each phase conductor and the external sheath are of an elastomeric plastics material.

5. A cable as claimed in any of the preceding claims in which one conductor of each pair of neutral conductors corresponding to two of the phase conductors is individually coloured with a corrosion-inhibiting paint for phase identification.

6. A cable as claimed in any of the preceding claims in which the metal tape is helically wound over the six neutral conductors with a small gap between successive turns.

7. An enveloped-neutral type, low-voltage electric cable substantially as hereinbefore described with reference to and as illustrated in the accompanying drawing.

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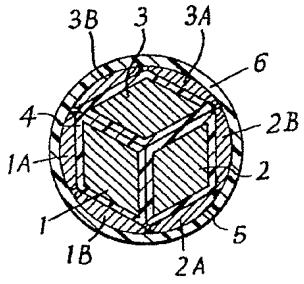
1362519 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*



Regulations of the Chinese Patent Law.

☒ The claims

Nos._____, the Chinese translation of the international application as originally filed;

Nos. 1-19, the Chinese translation of the amendment submitted under Article 34 of the Patent Cooperation Treaty.

Nos._____,the Chinese translation of the annexes of the International Preliminary Examination Report;

Nos._____, the Chinese translation of the amendment submitted under Article 28 or 41 of the Patent Cooperation Treaty;

Nos._____, amendment submitted according to Rule 51 of the Implementing Regulations of the Chinese Patent Law.

☐ The drawings

Pages_____, the Chinese translation of the international application as originally filed;

Pages_____,the Chinese translation of the annexes of the International Preliminary Examination Report;

Pages _____, the Chinese translation of the amendment submitted under Article 28 or 41 of the Patent Cooperation Treaty;

Pages_____, amendment submitted according to Rule 51 of the Implementing Regulations of the Chinese Patent Law.

5.☒ The following reference documents have been cited in this office action(their serial numbers will be referred to in the ensuing examination procedure):

Serial No.	Reference document(Number or Title)	Publication Date (or Filing date of interference patent applications)
1	"扇形紧压导体中单线排列结构及并线模的简化设计", 郭万斗, 《电线电缆》1994 年第 4 期, P12-15	day 08 month 1994 year
2	"200KV 1x1000mm2 大截面充油电缆的研制", 陈伟, 陈立军, 伊晓光, 赵军星, 《电线电缆》1999 年第 2 期, P9-11 .	day 04 month 1999 year
3	CN1097893A	25 day 01 month 1995 year
4	"导形导体结构设计的数学模型", 吴志宏, 《电线电缆》2001 年第 3 期, P17-21	day 06 month 2001 year

6. The result of the examination is as follows:

☒ Description:

☐ The subject matter of the application falls into the scope on which no patent right shall be granted as provided by Article 5 of the Chinese Patent Law.

☐ The description is not in conformity with the provisions of Article 26(3) of the Chinese Patent Law.

☒ The description is not in conformity with the provisions of Rule 18 of the Implementing Regulations of the Chinese Patent Law.

☒ Claims:

☐ Claim _____ falls into the scope within which no patent right shall be granted as provided by Article 25 of the Chinese Patent Law

Reference 1 :

Simplified Designs of Uniline Arrangement Structure in Sector-compacting Conductor and of Parallel-line Mold

Electric Wire & Cable No. 4 1994 P12-15

Reference 2:

Developing of Large-section Oil-filled Cable of 200KV & $1\times1000m^2$

Electric Wire & Cable No. 2 1999 P9-11

Reference 4:

Mathematical Models for Design of Profile Conductor structures

Electric Wire & Cable No. 3 2001 P17-21

中华人民共和国国家知识产权局

邮政编码：100083 北京市海淀区王庄路 1 号清华同方科技大厦 B 座 25 层 中科专利商标代理有限责任公司 刘晓峰	发文日期
申请号：2004800083348	

申请人：格鲁普通用电缆系统有限责任公司

发明创造名称：金属导体和制造其的过程

第一次审查意见通知书

（进入国家阶段的 PCT 申请）

1. ☑应申请人提出的实审请求，根据专利法第 35 条第 1 款的规定，国家知识产权局对上述发明专利申请进行实质审查。
   ☐根据专利法第 35 条第 2 款的规定，国家知识产权局专利局决定自行对上述发明专利申请进行审查。
2. ☑申请人要求以其在：
   ☐ 专利局的申请日 2003 年 03 月 28 日为优先权日，
   专利局的申请日 年 月 日为优先权日，
   专利局的申请日 年 月 日为优先权日。
3. ☐申请人于 年 月 日提交的修改文件，不符合专利法实施细则第 51 条的规定。
   ☐申请人提交的下列修改文件不符合专利法第 33 条的规定。
   ☐国际初步审查报告附件的中文译文。
   ☐依据专利合作条约第 19 条规定所提交的修改文件的中文译文。
   ☐依据专利合作条约第 28 条或 41 条规定所提交的修改文件。
   ☐ _____
4. ☐审查是针对原始提交的国际申请的中文译文进行的。
   ☑审查是针对下述申请文件进行的：
   ☑说明书 第 1-3 页，按照原始提交的国际申请文件的中文译文；
   第 _____ 页，按照国际初步审查报告附件的中文译文；
   第 _____ 页，按照依据专利合作条约第 28 条或 41 条规定所提交的修改文件；
   第 _____ 页，按照依据专利法实施细则第 51 条规定所提交的修改文件。
   ☐ _____
   ☐权利要求 第 _____ 项，按照原始提交的国际申请文件的中文译文；
   第 _____ 项，按照依据专利合作条约第 19 条规定所提交的修改文件的中文译文。
   第 _____ 项，按照国际初步审查报告附件的中文译文；
   第 _____ 项，按照依据专利合作条约第 28 条或 41 条所提交的修改文件；
   第 _____ 项，按照依据专利法实施细则第 51 条规定所提交的修改文件。
   ☑权利要求 1-19 项，按照依据专利合作条约第 34 条所提交的修改文件。
   ☐附图 第 _____ 页，按照原始提交的国际申请文件的中文译文；
   第 _____ 页，按照国际初步审查报告附件的中文译文；
   第 _____ 页，按照依据专利合作条约第 28 条或 41 条所提交的修改文件；
   第 _____ 页，按照依据专利法实施细则第 51 条规定所提交的修改文件。

☐_____

☑本通知书引用下述对比文献(其编号在今后的审查过程中继续沿用):

编号　　文件号或名称　　公开日期（或抵触申请的申请日）

1"扇形紧压导体中单线排列结构及并线模的简化设计",郭万斗,《电线电缆》1994 年第 4 期,第 12-15 页,1994 年 8 月

2"200kV 1×1000mm2 大截面充油电缆的研制",陈伟,陈立军,伊晓光,赵军星,《电线电缆》1999 年第 2 期,第 9-11 页,1999 年 4 月

3　　CN1097893A　　1995.1.25

4"异形导体结构设计的数学模型",吴志宏,《电线电缆》2001 年第 3 期,第 17-21 页,2001 年 6 月

5.审查的结论性意见:

☑关于说明书:

☐申请的内容属于专利法第 5 条规定的不授予专利权的范围。

☐说明书不符合专利法第 26 条第 3 款的规定。

☐说明书不符合专利法第 33 条的规定。

☑说明书的撰写不符合专利法实施细则第 18 条的规定。

☐_____

☑关于权利要求书:

☑权利要求1-4,8-10,14-16,18-19不具备专利法第 22 条第 2 款规定的新颖性。

☑权利要求5-7,11-13,17不具备专利法第 22 条第 3 款规定的创造性。

☐权利要求_____不具备专利法第 22 条第 4 款规定的实用性。

☐权利要求_____属于专利法第 25 条规定的不授予专利权的范围。

☐权利要求_____不符合专利法第 26 条第 4 款的规定。

☐权利要求_____不符合专利法第 31 条第 1 款的规定。

☐权利要求_____不符合专利法第 33 条的规定。

☐权利要求_____不符合专利法实施细则第 13 条第 1 款的规定。

☐权利要求_____不符合专利法实施细则第 2 条第 1 款关于发明的定义。

☑权利要求 7 不符合专利法实施细则第 20 条的规定。

☐权利要求_____不符合专利法实施细则第 21 条的规定。

☐权利要求_____不符合专利法实施细则第 22 条的规定。

☑权利要求 6 不符合专利法实施细则第 23 条的规定。

☐_____

上述结论性意见的具体分析见本通知书的正文部分。

6.基于上述结论性意见,审查员认为:

☐申请人应按照通知书正文部分提出的要求,对申请文件进行修改。

☐申请人应在意见陈述书中论述其专利申请可以被授予专利权的理由,并对通知书正文部分中指出的不符合规定之处进行修改,否则将不能授予专利权。

☑专利申请中没有可以被授予专利权的实质性内容,如果申请人没有陈述理由或者陈述理由不充分,其申请将被驳回。

☐_____

7.申请人应注意下述事项:

(1)根据专利法第 37 条的规定,申请人应在收到本通知书之日起的肆个月内陈述意见,如果申请人无正当理由逾期不答复,其申请将被视为撤回。

(2)申请人对其申请的修改应符合专利法第 33 条的规定,修改文本应一式两份,其格式应符合审查指南的有关规定。

(3)申请人的意见陈述书和/或修改文本应邮寄或递交国家知识产权局专利局受理处,凡未邮寄或递交给受理处的文件不具备法律效力。

(4)未经预约,申请人和/或代理人不得前来国家知识产权局专利局与审查员举行会晤。

8.本通知书正文部分共有 4 页,并附有下述附件:

☑引用的对比文件的复印件共 4 份 17 页。

☐_____

审查员:俞文良(A216)　　审查部门　　电学发明审查部

2006 年 12 月 12 日

回函请寄:100088 北京市海淀区蓟门桥西土城路 6 号　国家知识产权局专利局受理处收
(注:凡寄给审查员个人的信函不具有法律效力)

第一次审查意见通知书正文

申请号：200480008334.8

如说明书所述，本申请涉及一种金属导体和制造其的过程。经审查，现提出如下审查意见。

（一）

1.权利要求 1-4 不具有专利法第 22 条第 2 款规定的新颖性。

权利要求 1-4 要求保护一种用于电气和/或者通信电缆的金属导体，在对比文件 1（“扇形紧压导体中单线排列结构及并线模的简化设计”）中公开了一种用于电力电缆的金属导体，其中披露了以下技术特征：金属导体由多根导体（相当于本申请的金属丝的集成组件）通过紧压形成扇形（即本申请的包括一个弯曲侧的预定的多边形横截面）（参见第 12 页-第 15 页）。由此可见，对比文件 1 已经公开了权利要求 1-4 的全部技术特征。由于权利要求 1-4 与对比文件 1 技术领域相同，用相同的技术方案解决相同的技术问题，而且预期的技术效果也相同，所以，权利要求 1-4 不具有新颖性。

2.权利要求 5-7 不具有专利法第 22 条第 3 款规定的创造性。

权利要求 5-7 的附加技术特征是对金属丝的直径、绝缘材料层的材料进行限定，而金属丝的直径是实际生产过程中的一个最基本的参数，将其限定在 0.61mm 内是本领域技术人员惯用的技术手段；而在导体外包覆绝缘层，绝缘层采用聚乙烯、聚烯烃等等材料是本领域技术人员的公知常识，所以，在引用的权利要求不具有新颖性时，权利要求 5-7 不具有创造性。

3.权利要求 8-10 不具有专利法第 22 条第 2 款规定的新颖性。

权利要求 8-10 要求保护一种电气和/或通信电缆，在对比文件 2

（“200kV 1×1000mm² 大截面充油电缆的研制”）中公开了一种电气电缆，其中披露了以下技术特征：该电缆包括多个导体，其中导体由比较细的单线集合而成，导体呈扇形（即本申请的包括一个弯曲侧的预定的多边形横截面），导体电学地彼此绝缘，并且按顺序通过电缆形成过程覆盖在绝缘体内（参见第 9 页-第 11 页）。由此可见，对比文件 2 已经公开了权利要求 8-10 的全部技术特征。由于权利要求 8-10 与对比文件 2 技术领域相同，用相同的技术方案解决相同的技术问题，而且预期的技术效果也相同，所以，权利要求 8-10 不具有新颖性。

4. 权利要求 11-13 不具有专利法第 22 条第 3 款规定的创造性。

权利要求 11-13 的附加技术特征是对导体的形状进行限定，但是圆形导体是电缆生产过程中最常用的形状，而呈矩形、包括不同多边形横截面的形状分别在对比文件 3（CN1097893A）（参见说明书第 1-2 页）和对比文件 4（“异形导体结构设计的数学模型”）（参见第 17-21 页）中公开，而对于不同的结构的导体，本领域技术人员很容易从对比文件 3 和 4 中得到技术启示，将其中公开的内容用于对比文件 2 中，从而不需付出创造性劳动就能得到权利要求 12-13 要求保护的技术方案，所以，权利要求 11-13 不具有创造性。

5. 权利要求 14-16、18 不具有专利法第 22 条第 2 款规定的新颖性。

在对比文件 2（“200kV 1×1000mm² 大截面充油电缆的研制”）中公开了以下技术特征：导体外围绕有不锈钢带 11、内衬层 1、外护套（参见图 3）。由此可见，对比文件 2 已经公开了权利要求 14-16、18 的附加技术特征，所以，在引用的权利要求不具有新颖性时，权利要求 14-16、18 也不具有新颖性。

6. 权利要求 17 不具有专利法第 22 条第 3 款规定的创造性。

由于在导体外采用纺织材料作保护带是本领域技术人员在实际生产过程中惯用的技术手段，所以，在引用的权利要求 14 不具有新颖性

时，权利要求 17 不具有创造性。

7. 权利要求 19 不具有专利法第 22 条第 2 款规定的新颖性。

权利要求 19 要求保护一种金属导体的制造方法，在对比文件 2（“200kV 1×1000mm^2 大截面充油电缆的研制”）中公开了一种金属导体的制造方法，其中披露了以下技术特征：使用变形的机械装置对金属导体变形，所述金属导体包括用于实现预定多边形横截面的圆形金属丝组件，使用挤压装置挤压获得的金属导体（参见第 9 页-第 11 页）。由此可见，对比文件 2 已经公开了权利要求 19 的全部技术特征。由于权利要求 19 与对比文件 2 技术领域相同，用相同的技术方案解决相同的技术问题，而且预期的技术效果也相同，所以，权利要求 19 不具有新颖性。

虽然本申请不具有授权前景，但审查员还是就本申请中存在的其它缺陷一并予以指出。

8. 权利要求 7 不符合专利法实施细则第 20 条第 1 款的规定。

权利要求 7 中的“诸如”会限定出不同的保护范围，从而导致权利要求 7 保护范围不清楚。

权利要求 7 中的“丙稀”是不清楚的，从而导致权利要求 7 保护范围不清楚。

9. 权利要求 6 不符合专利法实施细则第 23 条第 2 款的规定。

权利要求 6 为多项从属权利要求，但其中又引用了多项从属权利要求，从而不符合“引用两项以上权利要求的多项从属权利要求不得作为另一项多项从属权利要求的基础”的规定。

另外，申请人应将权利要求 5-6 中的“前述任一所述”改为“权利要求 xx-xx 的任一项所述”这样的表述，以使引用的权利要求更清楚。

10. 说明书不符合专利法实施细则第 18 条第 3 款的规定。

说明书第 6 页第 2 行中的“丙稀”是不清楚的，从而导致说明书不清楚。

同时，提请申请人注意，对本申请中可能存在的类似缺陷申请人应一并予以修改。

（二）

综上所述，权利要求 1-19 要求保护的技术方案不具有新颖性和/或创造性，同时说明书中也没有记载其他任何可以授予专利权的实质性内容，因而即使申请人对权利要求进行重新组合或根据说明书记载的内容作进一步的限定，该申请也不具备被授予专利权的前景，除非申请人能够在本通知书指定的答复期限内提出充分理由，否则该申请将被驳回。如果申请人对申请文件进行修改，应当按照专利法第 33 条的规定，不得超出原说明书和权利要求书记载的范围。

另外，请申请人在提交修改文本的同时，提交修改部分的原文复印件，并在该复印件上标注出所作的增加、删除或替换，同时在修改处注明其得到原始公开文本支持的依据。

审查员：俞文良

TEL：010-62086306

D1

扇形紧压导体中单线排列结构及并线模的简化设计

四川电缆厂　郭万斗

摘要　针对扇形紧压导体的传统单线排列结构中要求有平行单线的缺陷，以及中心层为一根单线但最外层与相邻内层单线根数相差五根的不足，从统一单线直径与线芯排列结构稳定性出发，对截面为 35～300 mm² 的扇形紧压导体的单线排列结构，提出了中心层为一根单线及二至四根绞合单线、相邻两层单线相差六根的结构；同时提出了并线模的简化设计。实践证明，它们对简化工艺、方便管理、降低成本有一定意义。

主题词：扇形导体　紧压导体　结构　工模具　设计　改进

在众多的文献中，已对电力电缆扇形紧压线芯的紧压轮设计作了有益的探讨。精确计算压轮及扇形导体的结构尺寸，在工艺上是极为必要的，这是因为扇形导体的结构尺寸最终会影响到成缆的圆整性及成品电缆的外径大小，而且扇形导体的表面质量也会影响电缆的绝缘性能。

扇形紧压线芯质量的好坏，除了与单线质量、压轮结构尺寸设计是否合理等有关之外，同时与单线排列方式及并线模密切相关。因此，如何合理而经济地解决这类问题，是电缆生产中需要探讨的课题。

扇形导体结构中的单线排列

传统的观点认为，为了构成外形符合要求的扇形或半圆形线芯，其中心层都需要有平行单线，以利成型[1]。传统结构的单线排列有以下几种：

(1) 6+12(中心 6 根平行线)；

(2) 7+13(中心 7 根平行线)；

(3) 4+2+13(其中 2 根为平行线)；

(4) 7+2+15(其中 2 根为平行线)；

(5) 7+2+16(非规则绞合，其中 2 根为平行线)。

上述诸结构，由于中心层存在多根平行单线，当扇形导体经弯曲、平直后，中心层的平行单线易支出而变形[2]；而在边上排列的两根平行线，同样容易出现线芯跳位，造成压伤、飞边等质量问题。为此，文献[2]提出了中心层为 1 根单线的正规绞合结构。但是，如果对 35～300 mm² 的所有规格采用正规绞合结构以后，将会存在单线规格多、拉线复杂的问题。江苏宝胜电缆厂刘荣桂先生提出的力缆扇形导体采用统一单线直径的通径结构的构思[3]，对简化生产管理、提高效率具有很大的实用价值。但他提出的结构排列仍在边上保留有 2 根平行单线，而且某些规格最外层单线根数与倒数第二层单线根数相差 5 根，使线芯表面容易出现稀缝、漏缝。

根据这一状况，既考虑到单线直径的统一性，又考虑了到线芯排列结构的稳定性，现针对 35～300 mm² 扇形紧压导电线芯，笔者提出如下几种结构：

(1) 中心层为 1 根，每相邻两层相差 6 根的正规绞合结构(图1)。它适用于 35 mm²、95 mm²、185 mm² 及 300 mm²。

(2) 中心层以 2 根单线绞合，每相邻两层相差 6 根的结构(图 2)。它适用于 50 mm² 及 120 mm²。

(3) 中心层为 3 根单线绞合，每相邻两

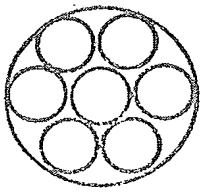


图 1

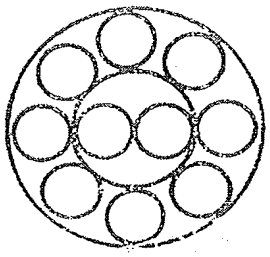


图 2

层相差 6 根的结构(图3)。它适用于240mm²。

(4) 中心层为 4 根单线绞合线芯，每相邻两层相差 6 根的结构 (图 4)。它适用于 70 mm² 及 150 mm²。

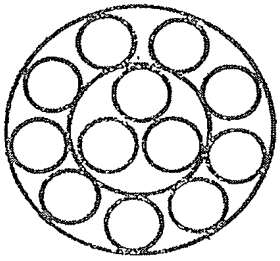


图 3

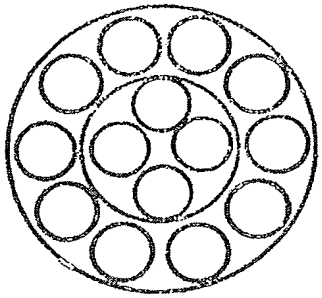


图 4

应指出的是，上述结构的排列方式，同样适用于半圆形线芯及 3+1 芯电缆的 60° 线芯。

为便于比较，兹将这类通径结构的线芯

表 1

标称截面 (mm²)	适用导体角度(°)	单线总数/单线直径	结构排列方式
35	180,120,100,90 60	7/d	1+6
50	180,120,100,90,60	10/d	2+8
70	180,120,100,90,60	14/d	4+10
95	180,120,100,90,60	19/d	1+6+12
120	180,120,100,90,60	24/d	2+8+14
150	180,120,100,90,60	30/d	4+10+16
185	180,120,100,90,*	37/d	1+6+12+18
240	180,120,100,90,*	48/d	3+9+15+21
300	180,120,100,90,*	61/d	1+6+12+18+24

* 对 3+1 芯电缆，当相线最大设计截面积为 300mm 时，其 60° 扇形第四芯只有 150mm²。

排列方式列于表 1。

在表 1 中，单线直径 d 由下式求出：

$$d=\sqrt{\frac{4S\lambda}{n\pi}} \qquad (1)$$

式中 d——单线直径，mm

n——单线根数

λ——紧压时单线的延伸系数

S——标称截面，mm²

这样的结构排列方式，一方面要满足统一的单线直径 d，另一方面不同规格导体又要符合一定的单线根数 n，而且 S 值不能太大也不能太小。

S 太大则耗料多，S 的选取以其相应规格的直流电阻值符合 GB 3957—83 的规定为宜。为此，可通过改变 λ 值来实现，即对不同规格选取不同的填充系数 η，η 与 λ 的关系曲线如图 5 所示[1]。

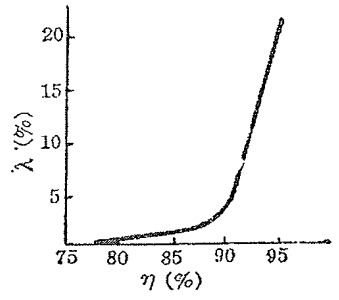


图 5 填充系数 η 与延伸系数 λ 的关系曲线

并线模的简化设计

按照传统的观点，半圆形及扇形线芯的紧压，是在圆单线构成的半圆形或扇形线芯的基础上进行的[1]。它要求线芯在紧压前就具备半圆形或扇形的卵形坯子。因此，它一方面要求在线芯排列方式上使用平行线结构，另方面需依靠并线模的孔型形状来实现初步成型。

尽管笔者提出的上述各种排列结构并不符合这一原则，但实践证明，只要压轮设计合理、节距选择适当（一般最外层节距倍数取10～14倍，对中心层为1根的正规绞合结构可取16倍左右），完全可以压制出所需要的扇形及半圆形的形状。换句话说，紧压前绞线结构形状与紧压后的导体形状并不要求具有一致性。这是因为铜、铝本身是一种具有良好塑性。变形的金属，它们在受到紧压时易于变形。因此，紧压线芯的最后定型，完全是靠紧压轮来实现的，并线模只起到定位稳固的作用，这也就为并线模的简化设计提供了可行性依据。有关并线模的简化设计情况，介绍如下：

(1) 材料　并线模的材料最好选用胶木，因为胶木具有一定的韧性和耐磨损性。采用胶木并线模后，不会造成使用钢模时因弹性差而使单线表面刮伤等的质量问题。

(2) 孔型形状　对于中心层为1～4根单线的导体，其第一道紧压轮之前的所有并线模，均可采用图6所示的圆孔型并线模，其模孔直径D为：

$$D = D_0 - (0.5 \sim 1.0) \quad \text{mm} \qquad (2)$$

式中D_0为紧压前绞线的计算外径(mm)；0.5～1.0为系数(经验值)，对中心层为1根的正规绞合结构取下限，其余可取上限。

对于多层绞合线芯，往往需要进行多次紧压，以提高填充系数。经过紧压的扇形或半圆形线芯，其下一道并线模的孔型如图7

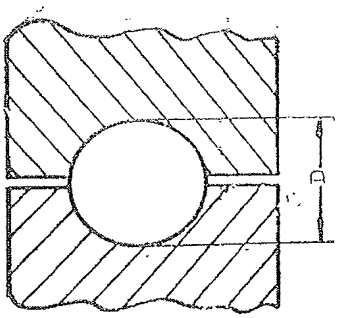


图6　圆孔型并线模

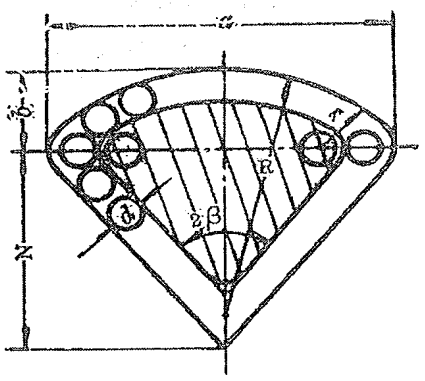


图7　扇形并线模孔型

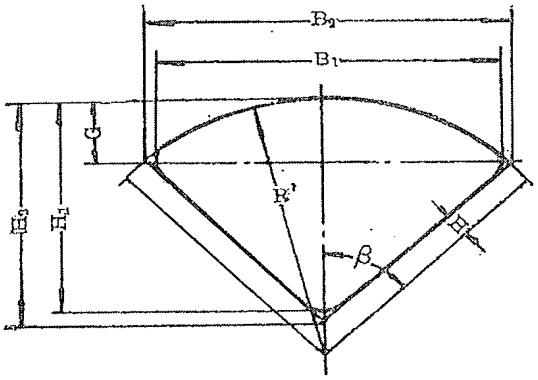


图8　扇形结构尺寸

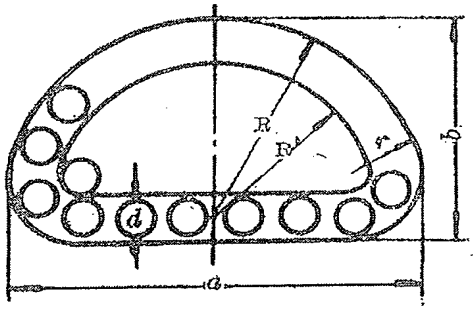


图9　半圆形并线模孔型

及图9所示。图7中的阴影部分为上道紧压后的扇形线芯，其图形尺寸如图8所示。

在图7中(参见图8)，

$$a = B_1 + 2d$$

$$b = G + d$$

$$N = H_2 - G + d/\cos\beta$$

$$R = R' + d$$

$$r = 1.5d$$

式中 a——并线模孔型宽度

b——并线模上半模孔型高度

N——并线模下半模孔型高度

R——孔型曲率半径

r——孔型边弧曲率半径

d——单线直径

B_1——上道紧压后的扇形线芯宽度

G——上道紧压后的扇形弓形高度

H_2——上道紧压轮孔型高度

R'——上道紧压后的扇形线芯曲率半径

β——扇形半角

在图8中：H为绝缘厚度；H_1为上道紧压后的扇形线芯高度；B_2为上道紧压轮孔型宽度。

在图9中：

$$a = 2R$$

$$R = R' + d$$

$$b = R + d$$

$$r = 1.5d$$

式中各参数说明与图7相同。

R'、B_1、B_2、H_1、H_2及G的精确计算，可参见文献[4]、[5]。

经这样简化以后，就可将并线模的设计由以往的6种[1]结构改变为以上三种，大大减小了并线模设计及加工工艺的复杂性。

结 束 语

从四川电缆厂的生产实践证明，本文介绍的扇形紧压导体中单线结构的排列方式及并线模的简化设计是切实可行的，它对简化生产工艺、方便管理、降低成本无疑具有积极的意义。

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成 缆 机 设 计 动 态

最近，由高级工程师王惠正为主设计的OL2+3/2000型成缆机，设计工作业已完成。

该设备的特点是：

(1) 主要用于10～35 kV大截面、大长度交联电缆的成缆，也可用于1 kV PVC绝缘塑力缆的成缆。由于二盘绞笼可与三盘绞笼同步旋转，因此，还可根据需要，应用于四芯塑力缆或五芯塑力缆的成缆。

(2) 根据一机多用的原则，本设备带有半切线式钢带绕包头1只，可兼用于大规格电缆(最大缆径ϕ108 mm)的钢带铠装。

(3) 本设备收、放线架的线盘型号规格为PN 3150，绞笼内放线盘型号规格为PN 2000。由于全部采用标准线盘，因此线盘容量大，并可确保大截面交联电缆的弯曲倍比。

(4) 牵引牙箱采用四只500型小牙箱组合而成。加工简单，体积小，成本低而变速范围大(36级)。

(5) 成缆填充用麻包头采用六只PN 500型线盘放线，容量大而操作方便。

(6) 设备价格仅为同规格盘绞式成缆机的三分之一至二分之一。 (顾宗模)

200 kV 1×1000 mm² 大截面充油电缆的研制

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摘要：本文讨论了大截面充油电缆研制的技术关键分割导体的设计和制造工艺，和其它有关的技术问题。

关键词：充油电缆；分割导体；工艺

引　　言

近年来，随着国民经济的发展，用电量猛增，开发高电压大截面充油电缆以满足高电压大容量输电和城网改造的需要势在必行。就国内目前情况来讲，大截面高压充油电缆主要依靠进口，国内的电缆厂一般只能生产 680 mm² 充油电缆，远不能满足发展的需要。为此，原机械工业部在 1992 年将 220 kV 大截面充油电缆列为部级新产品开发项目，上海电缆厂、红旗电缆厂和我厂等电缆厂随即进行了开发研制工作。

220 kV 1×1000 mm² 大截面充油电缆是沈阳电缆厂为上海供电局增设 220 kV 充油电缆线路而研制的。

开发大截面充油电缆存在一个关键性问题，就是随着导体截面增大，电缆传输容量并不随导体截面的增加而线性增加，造成这种现象的原因就是人们熟知的“集肤效应”和“邻近效应”。为了克服“集肤效应”和“邻近效应”，把导体损耗降止最小，采用分割导体是十分必要的。

分割导体的结构设计

一般来讲，大截面分割导体是由 4 股、5 股和 6 股扇形导体组成，而 4 股和 5 股分割导体多用于交联聚乙烯绝缘电缆，6 股扇形分割导体多用于有中心油道的充油电缆。

从制造工艺性来看，4 分割导体和 6 分割导体绞合成缆工艺容易进行，采用较为普遍，但从结构稳定性和弯曲性能来考虑，采用 5 分割导体是比较合理的。由于充油电缆中心油道有螺旋管支撑，所以 1000 mm² 充油电缆采用 6 分割导体结构，螺旋管外径为∅14 mm，扇形股块单线排列为 1+ 6+ 12+ 18 + 24，股块之间隔离采用成缆时股块间隔从股块内面平托一层绝缘皱纹纸。对于充油电缆，在国外也经常采用上述结构。也有在股块绞制时包绝缘作为股块之间的隔离，但在成缆时容易损坏，研制过程中也证明了这一点。

分割导体设计时填充系数的选择是十分重要的。分割导体股块即扇形股线绞合后欲得到稳定的形状，就必须进行压紧使其发生塑性变形。通过试制和参考国外的有关资料，对 1000 mm² 大截面充油电缆所用扇形股块的填充系数取 0.85～0.87 之间。

扇形导体股块压型工艺

扇形股块压紧有两种工艺，即一次压紧和分层（多次）压紧。一次压紧填充系数（紧压系数）为 0.8～0.84，而分层紧压填充系数（紧压系数）为 0.85～0.9，分割导体股块大多采用分层紧压。

分割导体扇形股块在紧压生产时，有预扭和非预扭两种形式。采用压紧后预扭的扇形股块经过绞线机牵引轮后，预扭节距略有变化，从而使股块绞合成缆时出现困难，但目前盘绞机带有自动调位装置，因此通常采用

预扭股块，其主要原因是为了成缆制造方便，而非预扭股块成缆工艺不易控制而不被采用。

由此，充油电缆 1000 mm² 分割导体采用分层紧压预扭扇形股块。工艺要点如下：

(1) 预扭头的设计；

(2) 扇形股块压轮及线模的设计；

(3) 扇形股线节距的确定。

根据绞线工艺设备的特点和要求，设计了充油电缆 1000 mm² 分割导体股块压轮和线模，确定压轮孔型如图 1 所示。

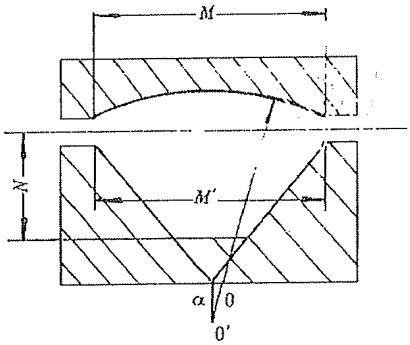

图 1　压轮孔型示意图

设计的技术关键是合理的扇形压轮孔型、圆心“O”的位置。为了使扇形股块压型后绞合成缆圆心重合，圆心“O”的位置不是扇形股块的圆心，而是在此圆心基础上，下移一个 a 值，对 1000 mm² 分割导体而言，a 值取为 0.3 mm，上下压轮之间的间隙取为 0.6 mm，以便工艺上的调整。

根据法国叉绞机的性能采用三层紧压预扭，这种方法制备的股块结构稳定，效果很好，因此在 12 盘、18 盘和 24 盘前分别采用孔型如图 1 所示的一对压轮。

分割导体扇形股线绞合成缆工艺

1000 mm² 分割导体是由 6 个扇形股块组成，股块之间用皱纹纸间隔，绞合成缆后，外面用一层 0.1 mm 厚不锈钢带扎紧，这一过程即为分割导体股块绞合成缆。扇形股块合成，一般绞入率为 0.01。预扭的扇形股块成缆后，预扭节距与绞合成缆节距应相符合，在一般情况下，预扭节距稍大于成缆节距，并且存在下列关系：预扭节距近似等于成缆节距的 1.2 倍。即使预扭节距和成缆节距控制得再精确，也避免不了它的微小误差。所以在成缆时，必须随时注意扇形的的正确位置，并在成缆机上设有校正扇形股块位置和节距的装置。

在成缆机上利用了如图 2 所示的自动调位装置。这种自动调位装置中压扇形股块部分在绞合成缆时，会左右摆动。当离开正常位置时，就能移动限位开关，从而校正股块到正常位置。

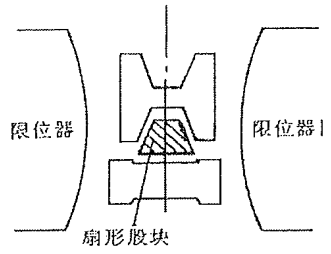

图 2　成缆机上自动调位装置示意图

在绞合成缆过程中，扇形股块的背部必须始终处在电缆周围部分，而扇形内小面积必须始终处在导体中心部位，否则制造的分割导体就不会圆整。

关于股间隔离带的实施，在盘绞机上设置了续绝缘皱纹纸的装置，它使皱纹纸导入绞合股块的内侧，每隔一个股块续一层绝缘皱纹纸效果良好，股间隔离带越薄越好，一般皱纹纸发皱厚度为 0.2～0.25 mm，发皱前厚度为 0.75 mm 的电缆线。

大截面充油电缆的结构

电缆绝缘的设计按照 IEC 141.1-93 的规定进行，雷电冲击水平为 1050 kV，绝缘厚度最小值取为 19.0 mm。按该绝缘厚度核算最大冲击场强为 68.77 kV/mm，而油纸绝缘厚度核算最大冲击击穿场强为 105 kV/mm，

则冲击绝缘的安全裕度为 1.37，而一般冲击绝缘安全裕度为 1.2 即可满足要求。在此绝缘厚度下，该电缆的最大工作场强为 10.65 kV/mm，而油纸绝缘的最大击穿电压为 40 kV/mm。采用三分之一搭盖时，油膜的最大场强 13.99 kV/mm，而 0.045 mm 厚的油膜的击穿场强为 91.65 kV/mm。

按以上的分割导体和电缆绝缘的设计，最终所确定的电缆结构如图 3 所示。

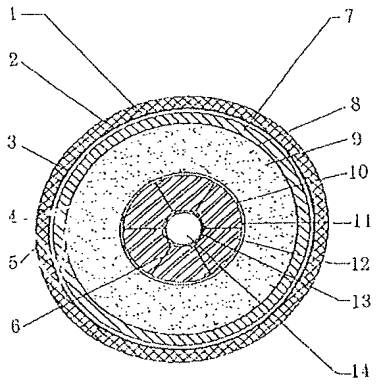

图 3　大截面充油电缆结构示意图
1- 内衬层　2- 加强层　3- 外被层　4- 外护套　5- 石墨层　6- 股间隔离　7- 铅层　8- 外屏蔽　9- 绝缘　10- 内屏蔽　11- 不锈钢带　12- 导电线芯　13- 螺旋管　14- 油道

研制过程中的几个问题

1. 纸包问题

1000 mm² 线芯外径比较大，也比较重。采用分割导体单线比较细时，可使得线芯比较柔软，有利于纸包质量，但由于线芯重，造成托纸包头中心孔的底部划伤线芯表面，以及扎紧不锈钢带串位卷边，影响纸包质量，为此在纸包机中心孔增加“井”字导轮，托起线芯，从而克服了这个问题。

2. 压铅

由于大截面充油电缆外径比较大，铅用量大，压铅速度慢，因此，控制好压铅机模座温度十分重要，否则压铅厚度不均匀，易造成偏心。另外重要的一点是盛铅筒冷却的控制。冷却控制不好会造成铅层表面出现波纹，冷却过大会产生多处停车点，甚至造成废品。为此，在研制时着重在这方面对操作者进行了培训，在实际试制中探索经验确保了产品研制的顺利进行。

3. 外护套

采用线性低密度聚乙烯护套。线性低密度聚乙烯除具有优良的机械性能和防水性能以外，还具有优良的耐电压性能，但对工艺过程要求较高。一是必须温水分段冷却，这一点容易解决，我们增了热水槽，并带有循环系统，保证水温在 60℃ 到室温之间调节，同时可节约用水；二是该材料在挤出进入水中后，护套表面容易产生“气泡坑”，因为水中有泡不易克服，经过严格控制工艺条件可以彻底克服这一问题。

产品试验及运行情况

我厂研制的 220 kV 1000 mm² 充油电缆经辽宁省电线电缆产品质量监督检测中心按 GB9326-88 所规定的项目进行了检测，其结果为各项指标均达到 GB9326-88 的要求，并且优于 IEC141.1-93 标准所规定的指标。其中，每盘电缆介质损耗角正切实际测试值为 0.0025，比标准要求值低 17% 以下；冲击水平实际测试值大于 1150 kV，比标准 1050 kV 高出 100 kV 还有裕度。

我厂研制的 220 kV 1000 mm² 充油电缆已批量生产。1997 年在上海敷设了 25 公里，目前已运行一年半多，用户反映良好。

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D3

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[54]发明名称 矩形铝电缆线

[57]摘要

矩形铝电缆线是与户外干式空心电抗器（专利号：91229139.7）配套用的导线，属特种电线类。

该线是由Φ1.5mm—Φ5.0mm多根单芯圆铝线绞合成多芯裸圆铝线，同时压制成矩形，四个角为R2mm。然后绕包聚酯薄膜三层和无碱玻璃丝带一层。矩形铝电缆线的试制成功，减小了户外干式空心电抗器的体积，降低了成本，为我国电缆事业开辟了一条新的途径。

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矩形铝电缆线

矩形铝电缆线是与户外干式空心电抗器(专利号:91229139.7)配套用于绕制线圈的导线，属特种电线类。

以前我国没有这种电抗器配套用的电缆线，所生产的水泥电抗器等均采用DKL型圆铝电缆，在生产户外干式空心电抗器中没有配套的电缆线，是我国电缆事业上的一个空缺。

为了解决上述不足，本发明的目的是为户外干式空心电抗器(专利号:91229139.7)配套而设计的一种新型的特种矩形铝电缆线，该线具有加工工艺简单，使用灵活，并具有高导电、高耐热等特点，耐热可达120℃以上，满足了户外干式空心电抗器的使用要求，提高了产品的配套水平，为我国电缆事业开辟了新的途径。

矩形铝电缆线是由∅1.5mm—∅5.0mm多根单芯圆铝线在专用设备上绞合成普通的裸铝绞线，同时压制成四个角为R2mm的矩形铝电缆线，然后用0.03mm—0.05mm聚脂薄膜绕包三层，聚脂薄膜采用重叠50%的方式绕包，中间允许有接头，但不准有断头现象，最后采用无碱玻璃丝带绕包一层，并采用搭接40%的方式绕包，无碱玻璃丝带的厚度为0.15mm。在绞合前必须将单芯圆铝线的油污，杂物清理掉。压制的矩形铝线的几何尺寸厚在5mm—20mm之

间，宽在7mm—25mm之间，其偏差在±0、1mm内，截面积在25mm²—400mm²之间。电缆线的制造长度应按用户规定加工，规定长度内不准有接头。该电缆线的最大电流可达500安培。总的绝缘厚度在0、5mm—0、7mm之间。

矩形铝电缆线属特种电线类，具有加工工艺简单，可在专用设备上进行加工制造，并且规格全，使用灵活，是户外干式空心电抗器理想的配套产品。

矩形铝电缆线是由机械加工压制而成的，主要是由多根的单芯圆铝线绞合成普通的大截面的多芯裸圆铝电缆线，同时压制成矩形，其几何尺寸厚为5mm—20mm，宽为7mm—25mm之间，截面积在25mm²—400mm²之间，电缆线的最大电流为500安培，然后用0、03mm—0、05mm聚脂薄膜重叠50%方式绕包三层，中间允许有接头，但不许有断头现象，最后采用无碱玻璃丝带搭接40%方式绕包一层，无碱玻璃丝带的厚度为0、15mm。总的绝缘厚度为0、5mm—0、7mm之间。本发明的矩形铝电缆线是与户外干式空心电抗器（专利号：91229139、7）配套用的理想特种电线，为我国电缆事业开辟了一条新的途径。

权　利　要　求　书

1、矩形铝电缆线是与户外干式空心电抗器(专利号：91229139、7)配套用于绕制线圈的特种电线，其特征在于矩形铝电缆线是由多根单芯圆铝线在专用设备上绞合成多芯裸圆铝线，同时压制成矩形，然后用聚脂薄膜绕包三层，最后绕包无碱玻璃丝带一层。

2、根据权利要求1所述的矩形铝电缆线其特征在于单芯圆铝线上机绞合前除掉油污和杂物，单芯圆铝线的直径为∅1、5mm—∅5、0mm。

3、根据权利要求1、2所述的矩形铝电缆线，其特征在于用∅1、5mm—∅5、0mm多根单芯圆铝线在专用设备上绞合成多芯裸圆铝线，同时压制成矩形，其四个角为R2mm。

4、根据权利要求1、3所述的矩形铝电缆线，其特征在于压制后的矩形铝电缆线外用0、03mm—0、05mm聚脂薄膜采用重叠50%的方式绕包三层。

5、根据权利要求1、4所述的矩形铝电缆线，其特征在于绕包三层聚脂薄膜后再绕包一层无碱玻璃丝带，玻璃丝带厚度为0、15mm。并采用搭接40%的方式绕包。

6、根据权利要求1、3所述的矩形铝电缆线，其特征在于压制后的矩形铝电缆线的几何尺寸厚为5mm—20mm，宽为7mm—25mm之间，其偏差在±0、1mm内，截面积在25mm²—400mm²之间。

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7、根据权利要求1所述的矩形铝电缆线其特征在于电线的规定长度内不准许有接头。

8、根据权利要求4、5所述的矩形铝电缆线，其特征在于总的绝缘厚度在0、5mm—0、7mm之间。

D4

导形导体结构设计的数学模型

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摘要: 介绍了采用BASIC 编程和"牛顿迭代法", 利用半圆形、扇形和瓦形导体及其组合的多芯导体结构设计的数学模型, 研制了"异形导体结构优化设计"的软件包, 经工艺人员使用, 反映操作简便, 图表并茂, 设计快捷, 具有一定的实际使用价值。

关键词: 多芯电力电缆; 异形导体; 结构设计; 数学模型; 牛顿迭代法; 软件包
中图分类号: TM 247.1 文献标识码: A 文章编号: 31-1392(2001)03-0017-05

Mathematical models for design of profile conductor constructions

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Abstract: This article presents mathematical models for design of multiple conductor constructions consisting of semi-circle conductors, sector-shaped conductors and segment conductors and their combinations using BASIC programming and Newton iteration. A software pack called optimized design of profile conductor construction was developed, which was welcome by process engineers for easy use, picture/chart description and fast design.

Key words: multiple conductor power cable; profile conductor; construction design; mathematical modle; Newton interation; software pack

1 前 言

电缆的异形导体结构设计虽有不少资料介绍, 但仅限于几种典型结构。作为一名电缆工艺人员, 由于大多并不熟悉BASIC 编程和"牛顿迭代法", 因而总是被动地接受计算机人员的"指导", 不能自主地运用现代化工具对异形导体结构设计做深入的研究, 当然也谈不上优化设计。另外市场上"非标"结构的电缆多了起来, 只有采用现代化的设计工具才能以不变应万变, 快速满足客户需要。有鉴于此, 笔者运用 EXCEL + 宏技术开发的"异形导体结构优化设计"软件包进行异形导体结构优化设计的工具, 以提高工作效率。所谓异形导体结构主要是由半圆形、扇形和瓦形以及由其组合的多芯电缆结构, 目前已达十多种。要达到优化设计的目的, 就必须对这十几种结构都进行设计, 然后比较各种结构参数进行优选。利用本设计方法, 例如对三瓦二等圆结构, 看上去是一种较理想的结构, 工艺上也容易实现, 但通过本软件设计你会发现它并不是一种完整的结构, 然而, 如果将两圆改成一大一小或同时减小直径, 则又可以使其变为完整的结构, 这就是所谓的"非标"结构。本软件操作简便, 图表并茂。数据录入、导体及压轮参数全部在一张表上直观显示, 同时采用手工迭代输入(迭代次数仅 2~3 次)更使您体验"牛顿迭代法"的乐趣。以下是软件设计的数学模型, 你可据此模型设计自己的软件包。

收稿日期: 2000-11-30
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2 通用公式

以下公式是各种异型导体结构设计中都要用到的基本公式:

计算截面 $S_j = 0.7854 d^2 N / N / \mu$

实际截面 $S_s = 0.7854 d^2 N / \mu$

内弧半径 $R_1 = K_1 S^{1/2}$ $R_2 = K_2 S^{1/2}$

角度转换 $\beta' = \pi/180 \times \beta = 0.01745\beta$

式中: S 为标称截面; d 为单线直径; N 为单线根数; λ 为紧压系数(0.85~0.88); μ 为延伸系数 1.04; K_1, K_2 为修正系数, 选用值见表 1。

表 1

	$2\beta \leqslant 90^\circ$	$90^\circ < 2\beta \leqslant 105^\circ$	$105^\circ < 2\beta \leqslant 180^\circ$
K_1	0.85	0.80	0.64
K_2	0.54	0.60	0.64

说明: 计算截面 S_j 为紧压后含有空隙的异型导体结构面积; 实际截面 S_s 是紧压后异型导体的有效截面积, 用以与标称截面(产品标准参数)进行比较;

内弧半径 R_1 也即异型导体结构的边弧半径; β 为大弧半角, 后两种结构参数的几何含义请参阅下文相应的数学模型图。本文以下图形(图 1～图 16)和公式适用于本文所述的瓦型、扇型和半圆形导体结构:

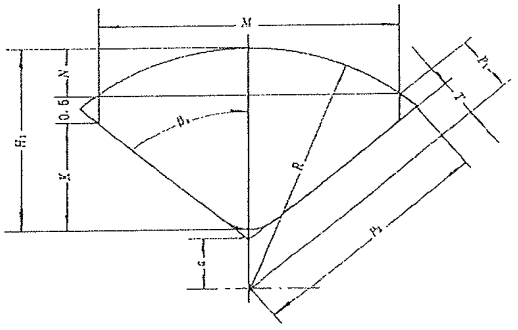

图 1

3 压轮几何尺寸计算(图 1)

$$M = 2[P_2 \times \sin\beta_r - P_1 \times \cos\beta_r]$$

$$N = R - P_1 \times \sin\beta_r - P_2 \times \cos\beta_r$$

$$P_1 = T + 0.5 \times \sin\beta_r$$

$$P_2 = \sqrt{R^2 - P_1^2}$$

$$\beta_r = \beta - 0.5^\circ$$

$$K = H_1 - N - 0.5$$

$$a = T/\sin\beta_r$$

R、β、H_1 为设计得到的异型导体结构参数, T 为标准给定的绝缘厚度, 已知以上四个参数就可以据此设计压轮尺寸。β_r 是 β 的修正值。

4 瓦形结构

4.1 数学模型及结构参数(图 2)

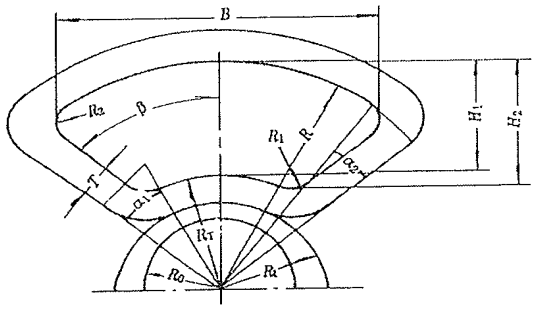

图 2

$$S_J = R^2 \times (\beta - \alpha_2) - R_1^2 \times \alpha_1 + R_2^2 \times \alpha_2 + (R_2^2 - T^2)/\mathrm{tg}\,\alpha_2 + (R_1^2 + R_2^2) \times \pi/2 + (T^2 - R_1^2)/\mathrm{tg}\,\alpha_1 - (R_1 + T)^2 + (\beta - \alpha_1)$$

$$f(R) = R^2 \times (\beta - \alpha_2) - R_1^2 \times \alpha_1 + R_2^2 \times \alpha_2 + (R_2^2 - T^2)/\mathrm{tg}\,\alpha_2 + \pi/2 \times (R_1^2 + R_2^2) + (T^2 - R_1^2)/\mathrm{tg}\,\alpha_1 - (R_1 + T)^2 \times (\beta - \alpha_1) - S_J$$

$$f'(R) = 2 \times R \times (\beta - \alpha_2) + 2 \times R_2[(R + T)/(R - 2 \times R_2 - T)]^{1/2}$$

$$R_{n+1} = R - f(R)/f'(R)$$

$$\alpha_1 = \arcsin[(T + R_1)/(R_1 + R_1 + T)]$$

$$\alpha_2 = \arcsin[(T + R_2)/(R - R_2)]$$

$$H_1 = R - R_1 - T$$

$$H_2 = R + R_1 \cos(\beta - \alpha_1) \times (R_1 + R_T)$$

$$B = 2 \times [R_2 + (R - R_2) \times \sin(\beta - \alpha_2)]$$

$$L = 2 \times [R \times (\beta - \alpha_2) + R_2 \times \alpha_2 - R_1 \times \alpha_1 + \pi/2 \times (R_1 + R_2) + (R_2 + T)/\mathrm{tg}\,\alpha - (R_1 + T)/\mathrm{tg}\,\alpha_1 + (R_1 + T)(\beta - \alpha_1)]$$

$$D_x = L/\pi \text{(当量圆直径)}$$

以上数学模型的建立请参阅文献[1], H_2 为紧压导体的工艺控制参数。

4.2 4+1 与 3+2(1)结构设计(图 3, 4)

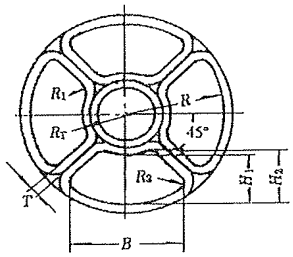

图 3

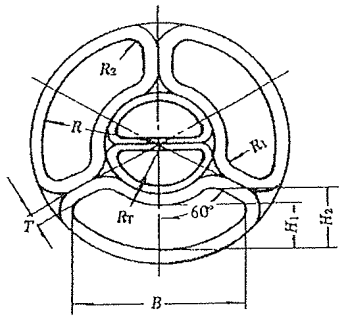

图 4

以上两种结构属全对称结构(即 X-Y 轴对称), $\beta = 90^\circ$ 或 120°, 可在 EXCEL 中编写简单的宏函数直接用牛顿迭代法求出 R。

4.3 3+2(2)结构设计(图 5)

此种结构属半对称结构, 大瓦与小瓦的 R、β 相互关联, 即:

$$R_{小} = R_{大} + T - t$$

$$\beta_{小} = [S_J + R_{大}^2 \times \alpha_2 + r_1^2 \times \alpha_1 - r_2^2 \times \alpha_2 - (r_2^2 - t^2)/$$

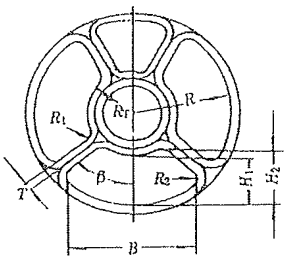

图 5

$\mathrm{tg}\,\alpha_2 = (r_1^2 + r_2^2)\pi/2 - (r_2 - r_1)/\mathrm{tg}\,\alpha_1 - (R_1 + t)^2 \times \alpha_1]/[R_{平}^2 - (R_1 + t)^2]$

$\beta_{大} = (180 - \beta_{小})/3$

对此种结构，我们在 EXCEL 中利用手工迭代方法，这样可以避免较复杂的宏编程。为此，在设计表格的时候引入 $R_{手工}$ 参数，然后强迫 $R_{手工} = R_{大}$，通过非常有限的迭代次数(2～3 次)即可使 $R_{手工}$ 逼近 $R_{大}$，此时 $R_{手工}$ 即为所求。计算流程如下：

$R_{手工} \rightarrow R_{小} \rightarrow \beta_{小} \rightarrow \beta_{大} \rightarrow R_{大} \rightarrow \cdots\cdots$(迫使 $R_{手工} = R_{大}$)

4.4 3+2(3)结构设计(如图 6)

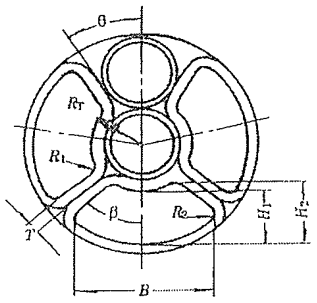

图 6

以上地线线芯为等圆结构，$R = 3R_1$，$\theta = 30°$，$\beta = (180° - 30°)/3 = 50°$，其 β 为定值，设计流程：根据已知的 R、β 计算 Sj，然后根据 $Sj = 0.7854 \times d^2 \times N / \lambda/\mu$ 计算出 λ。根据标准规格设计结果，发现此种结构的 λ 低于 0.85 许多，故对于标准规格不适用。但如果同时减小两地芯绝缘半径 R_1(非标规格)则值得考虑，设计思路是根据 λ 来调整两地线线芯绝缘半径，使 $\lambda = 0.85 \sim 0.88$。

4.5 3+2(4)与 3+2(5)结构设计(图 7, 8)

与前述结构不同的是，两地线线芯采用一大一小圆形结构，适用于非标设计。

$R = R_{小} + 2R_2 - T$

$\sin\theta = R_2/(R_2 + R_{小})$

$\beta = (180 - \theta)/3$

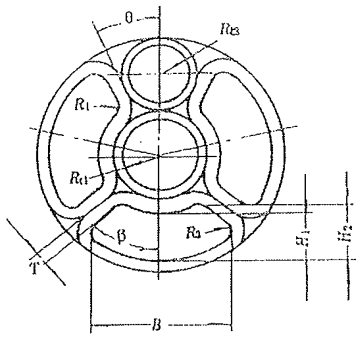

图 7

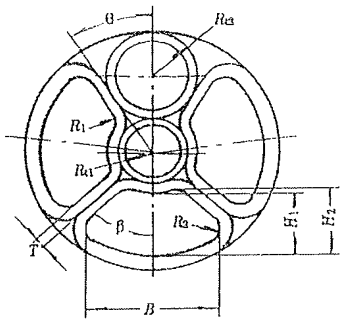

图 8

设计思路：根据已知的 R、β 算出 Sj，再根据 $0.7854 \times d^2 \times N / Sj/\mu$，求 λ，根据 λ 的结果调整 R_1 和 R_2，以使 λ 在 0.85～0.88 之间。

5 扇形结构

5.1 数学模型及结构参数(图 9)

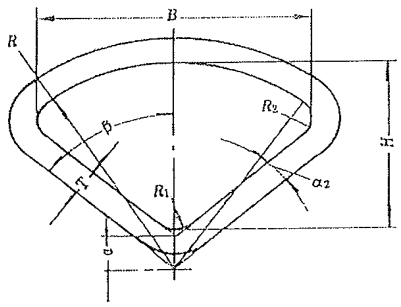

图 9

仔细观察比较扇形与瓦形结构，不难发现当瓦形的 $\alpha_1 = \beta$ 时，瓦形即变成了扇形，公式调整如下

$Sj = (R^2 - R_1^2) \times \beta - (R^2 - R_2^2) \times \alpha_2 + (R_2^2 - T^2)/\mathrm{tg}\,\alpha_2 + (R_1^2 + R_2^2)\pi/2 + (T^2 - R_1^2)/\mathrm{tg}\,\beta$

$\alpha_2 = \arcsin[(T + R_2)/(R - R_2)]$

$f(R) = (R^2 - R_1^2) \times \beta - (R^2 - R_2^2) \times \alpha_2 + (R_2^2 - T^2)/\mathrm{tg}\,\alpha_2 + (R_1^2 + R_2^2)\pi/2 + (T^2 - R_1^2)/$

$$\text{tg}\ \beta - Sj$$

$$f'(R) = 2\times R\times(\beta - \alpha_2) + 2\times R_2\times[(R+T)/(R-2R_2-T)]^{1/2}$$

$$R_{n+1} = R - f(R)/f'(R)$$

$$H = R + R_1 - (T + R_1)/\sin\beta$$

$$B = 2[R_2 + (R - R_2)\times\sin(\beta - \alpha_2)]$$

$$L = 2\times[R\times(\beta - \alpha_2) + R_1(\pi/2 - \beta) + R_2\times(\pi/2 + \alpha_2) - (R_1 + T)/\text{tg}\ \beta + (R_2 + T)/\text{tg}\ \alpha_2]$$

$$D_x = L/3.14$$

5.2 三等芯与四等芯结构设计(图 10, 11)

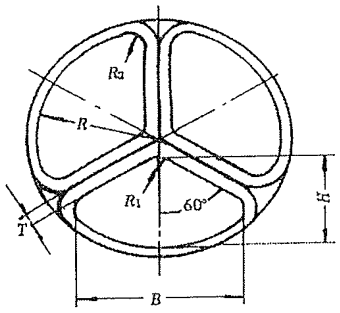

图 10

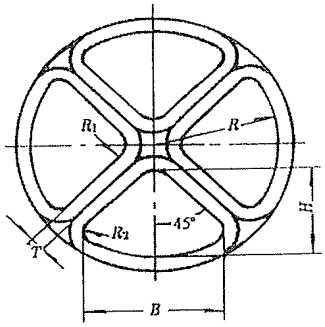

图 11

此种结构为全对称结构, β 为已知值, 故可在 EXCEL 中编写简单的宏函数直接用牛顿迭代法计算出 R, 继而求出其它参数。

5.3 3+1(1)与 3+2 结构设计(图 12, 13)

$$R = R_1 + R_1/\sin\theta - T;$$

$$\sin\theta = R_1/(R + T - R_1);$$

$$\beta = (180 - \theta)/3。$$

这是一个半对称结构, 故仍采用手工迭代法。计算流程如下: $R_{手工}\rightarrow\theta\rightarrow\beta\rightarrow R$; 对 3+2(两半圆形地芯)结构, 通过手工迭代发现, 有些标准规格函数是发散的, 即 $R_{手工}$ 不管迭代多少次都逼近不了 R_{n+1}。

5.4 3+1(2)结构设计(如图 14)

$$\beta_{大} = (180 - \beta_{小})/3$$

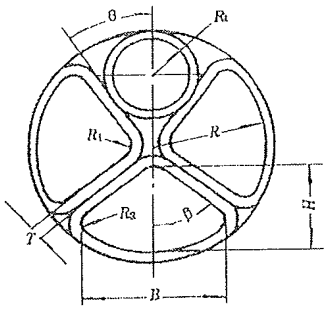

图 12

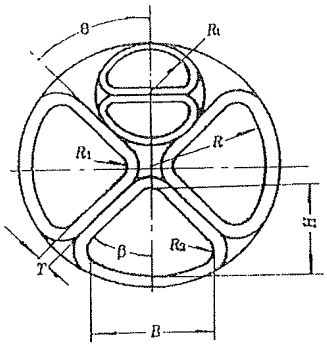

图 13

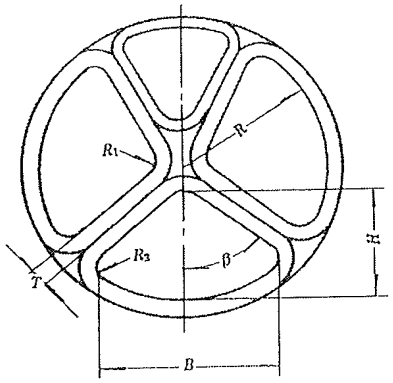

图 14

$$f(\beta_{小}) = \beta_{小}\times(R^2_{小} - r_1^2) + (t^2 - r_1^2)/\text{tg}\ \beta_{小} + (r_2^2 - t^2)/\text{tg}\ \alpha_2 + (r_1^2 + r_2^2)\times\pi/2 - (R^2_{小} - r_2^2)\times\alpha_2 - Sj$$

$$f'(\beta_{小}) = (R^2_{小} - r_2^2) - (t + r_1)^2/(\sin\beta_{小})^2$$

$$\beta_{小(n+1)} = \beta_{小} - f(\beta_{小})/f'(\beta_{小})$$

$$R_{小} = R_{大} + T - t$$

本结构函数求导后由于含有超越方程, 大小扇形的 R、β 相互牵制, 故此种结构最为复杂, 需进行双重迭代。计算流程如下

$$R_{大(手工)}\rightarrow R_{小}\rightarrow\beta_{小}\rightarrow\beta_{小(手工)}\rightarrow\beta_{大}\rightarrow R_{大}\rightarrow\cdots$$

$R_{实际值}=R_{实}$

$\beta_{新}\rightarrow\beta_{实}\rightarrow R_{实}\rightarrow R_{实际值}\rightarrow R_{新}\rightarrow\beta_{新}\rightarrow\cdots$

$\beta_{新}=\beta_{新}$

以上两步迭代既可交叉进行，也可单独进行，单独进行时，不考虑$R_{实际值}$或$\beta_{新}$最终结果必须使$R_{实际值}=R$和$\beta_{新}=\beta_{新}$同时满足。

5.5 2+1结构设计(图15)

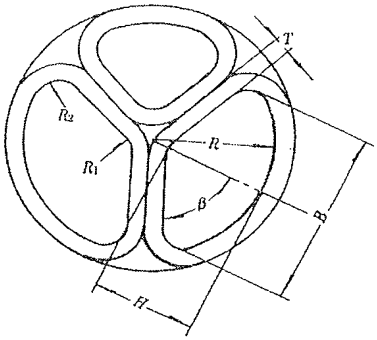

图 15

此类结构数学模型与设计方法由3+1派生。但$\beta_{实}=(180-\beta_{新})/2$，计算流程与3+1(1)相同。

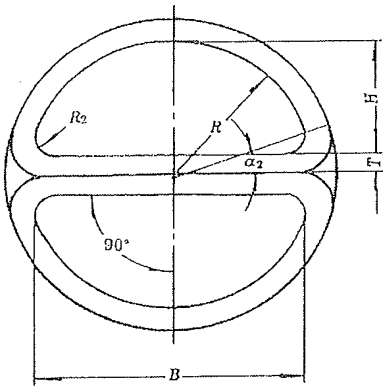

图 16

6 半圆形数学模型(图16)

仔细观察扇形结构数学模型可发现，当$\beta=180$时，扇形即变成了半圆形

$$Sj=\pi/2(R^2+R_2^2)+\alpha(R_2^2-R^2)+(R_2^2-T^2)\times\mathrm{ctg}\,\alpha$$

$$R=\sqrt{\frac{Sj-R_2^2(\pi/2+\alpha)-(R_2^2-T^2)\times\mathrm{ctg}\,\alpha}{\pi/2-\alpha}}$$

$$\alpha=\arcsin(R_2+T)/(R-R_2)$$

$$L=2[(\pi/2-\alpha)\times R+R_2(\pi/2+\alpha)+(R_2+T)\times\mathrm{ctg}\,\alpha]$$

$$B=2[R_2+(R-R_2)\times\sin(\pi/2-\alpha)]$$

$$D_c=L/3.14$$

此结构为全对称结构，故可编写简单的宏函数进行处理，只要输入结构参数，则可自动计算出所有结果。

压轮几何参数(图17)

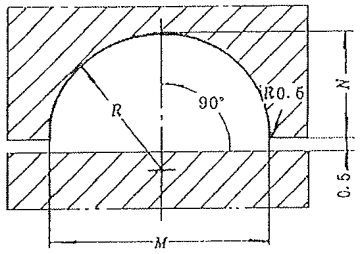

图 17

$$N=H-0.5$$

$$M=2\times\sqrt{R^2-(R-N)^2}$$

7 软件包的应用

笔者根据以上数学模型制作的软件包经工艺人员使用，反映操作简便，图表并茂，设计快捷。只要输入或调整参数便可立即得出包括紧压轮在内的全部结果参数。有些结构虽需手工迭代，其操作也很方便，一般只需迭代2～3次(视保留的小数位数)，几秒钟便可完成。当然也可以编写较复杂的宏程序让计算机自动计算，但在此不大必要，程序一复杂，工艺人员也难以理解该软件包的设计原理和过程。

该软件包基本上满足了典型或非标电缆异形导体结构设计，工艺人员再也不用加班加点地熬夜了。根据本软件包设计的紧压轮已在本公司实际推广应用。

参考文献：

[1] 郭万生，杨 辉，肖建华. 大截面五芯电力电缆的结构设计[J]. 电线电缆. 1992 (3).